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# ENGINEERING:

## An Illustrated Weekly Journal.

*EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.*

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*See Illustrated Advt. in alternate issues.* Od 3382

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*See half-page Advertisement, last and next week.*

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IN THE MATTER OF THE TRADING WITH THE ENEMY AMENDMENT ACT 1916.

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Before any Tender is accepted the proposed Purchaser will be required to make a statutory declaration that he is a British subject and that he is not buying for or on behalf of a foreigner or foreign corporation or company under foreign control.

A Report on the past operations and the present position of the Company has been prepared for the Public Trustee by Messrs. Litton, Pownall, Blakey and Higson, Chartered Accountants, and this Report can be inspected either at their Offices, No. 42, Spring Gardens, Manchester, or at the Offices of the Public Trustee, Kingsway, London, W.C.

Conditions of Sale and Forms of Tender may be obtained at the offices of Messrs. Litton, Pownall, Blakey & Higson, or at the offices of the Public Trustee, and all Tenders will be subject to such conditions.

All Tenders must be delivered in sealed envelopes to the Public Trustee on or before Twelve o'clock noon on the 1st day of October, 1917, and must be marked "Tenders. Schaffer and Budenberg Co.'s Shares," and the successful tenderer will be advised of the acceptance of his tender within one week thereafter.

The Purchaser will be entitled to all profits shown by the Balance Sheet of the Company dated the 31st day of December, 1916, and to all profits of the Company subsequently earned. H 708

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## Superintendent Wanted, for

a large factory in the West of England, for simple mechanical repetition work. Must be a Six o'clock man, accustomed to the control of large numbers of female workers. No person already employed on Government work will be engaged.—State age, full particulars of experience and salary expected to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and H 884.

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Candidates should have had a good workshop experience, qualifications in machine drawing will be a recommendation.

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Further information may be obtained from the undersigned, to whom applications should be sent as early as possible.

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## Instructor in Practical Mathematics, Mechanical Drawing, &c., for Classes

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REQUIRE in the immediate future a Practical Foundry Manager to act for the present as Assistant to the Foundry General Manager with a view of assuming control of that Department, which employs about two thousand men, as soon as practicable. A knowledge of Pipe Foundry not essential.—Applications, giving full particulars of past experience, should be addressed to the FOUNDRY GENERAL MANAGER. H 701

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Write to F.P., SELLS, Ltd., Fleet Street, E.C. 4.

H 911

## Assistant Works Superintendent (progressive position) WANTED by

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## Night Superintendent for

Government Controlled Works in London district. Must be good engineer, thoroughly conversant with automatic machine tools for mass production of small accurate parts; must also be good organiser and strong disciplinarian. No person resident more than 10 miles away, or already on Government work will be engaged.—Apply by letter in first instance, stating age, experience and salary required, to S.T. 453, SELL'S Ltd., Fleet Street, E.C. 4. H 921

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for hardening dept. in large engineering works. Knowledge of case hardening small parts in large quantities essential. Progressive position. No one engaged on Government work will be engaged without consent of present employer.—Write giving fullest particulars to your nearest EMPLOYMENT EXCHANGE mentioning this Journal and H 912.

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for Manager's Office, large engineering firm in Manchester district. Good stenographer, accustomed to engineering terms. Up-to-date office arrangements, &c. No person already on Government work will be engaged. State age, full details of experience and salary required.—Apply, your nearest EMPLOYMENT EXCHANGE, quoting No. A 3566. H 863

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## A Government Controlled

Establishment DESIRES to EMPLOY a live MAN to take charge of modern Repetition Machine Shop employing 100 hands. A good salary and bonus will be paid to a first-class man of ability and experience. No one already employed on Government work will be engaged.—Apply, stating age, experience and salary required to nearest EMPLOYMENT EXCHANGE, mentioning this Journal and H 882.

## Wanted, an Assistant to Shop

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RATE FIXER for large Controlled Establishment of Engine Builders; must be first-class man of wide experience in this class of work. Capable of training a staff and re-organising a department. Permanent position and good prospects for suitable applicant. No one already on Government work will be engaged.—State age, experience and salary required to your nearest EMPLOYMENT EXCHANGE, quoting this Journal and No. 3746. H 920

## Wanted at Once, Good All-

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## Wanted, First-class Practical ENGINEER as Works' Manager by im-

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## Wanted, by an Old-estab-

lished Firm engaged on Aircraft, a Capable Production ENGINEER. Must have full knowledge of modern methods of production, jig work and press tools, be energetic and tactful. Must be a Six o'clock man. Give full details when replying, general statements will not receive consideration. No man engaged on Government work will be engaged.—Apply your nearest EMPLOYMENT EXCHANGE, quoting this Journal and H 909.

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## Wanted, Good First-class

TOOL ROOM FOREMAN, used to Medium and Heavy Work, for large controlled establishment, Manchester District. No one on Government work will be engaged. State age, experience and wages required.—Apply, your nearest EMPLOYMENT EXCHANGE, quoting No. A 3603. H 804

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Aluminium Foundry on Motor and Aircraft Castings. Government work. Must be thoroughly experienced, organiser, familiar with modern machine moulding. American experience desirable. Good salary and commission to right man. Permanency.—Apply to your nearest EMPLOYMENT EXCHANGE, stating age, salary required and full details as to qualifications, quoting No. A 3713. No one on Government work need apply. H 855

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# ON THE ANALYSIS OF THE RESULTS OF INCLINING EXPERIMENTS.

By C. FRODSHAM HOLT, B.Eng., A.M.I.N.A.

§1. A great part of the duty of the naval architect consists in the exercise of a trained judgment or scientific common-sense in the correlation of, or in making a sound compromise between, a large number of interdependent, yet conflicting, physical phenomena, few of which yield to any absolute scientific treatment. Perhaps his work in connection with inclining experiments forms one of the simplest of his tasks; yet even here there occur many possibilities of error; in addition to the treatment of the experimental observations, there is involved an analysis of a mass of data dealing with the condition of the vessel, which depends entirely on the skill and judgment of the man in charge of the experiment. His aim is to arrive at the stability in a standard condition of completeness and loading; and meticulous accuracy is essential, as the result affords not only a criterion of the safety of the immediate subject of the experiment, but also a basis from which many future designs will be developed. On this account anything that tends to eliminate a chance of error is worthy of consideration, as it will render the successful accomplishment of his task more certain. Yet there remains one source of possible error that is rarely, if ever, taken into consideration; this forms the subject of this note. The object, therefore, with which this is written is not to advocate any change in the present manner of making the experiments; it is rather to show how this particular type of error may practically be eliminated.

The practical application of this investigation may be briefly indicated. It is shown that if the calculation of the initial stability is based on the relations suggested it is unnecessary to use more than the minimum amount of water ballast required for safety, even if the vessel is unstable when inclined; it is often the case that 300 or 400 tons of water ballast are added, thus introducing a possibility of considerable error. But it is also shown that if the usual formula is used, it is better to risk this possibility in order to avoid the certainty of inaccuracy involved if the vessel has low stability.

§2. In the course of a paper read before the Institution of Naval Architects in 1904, "On the Heeling and Rolling of Ships of Low Initial Stability,"* Professor Scribanti suggested that the results he obtained might be of use in dealing with inclining experiments. It is proposed to adopt this suggestion, and to indicate the possibility and nature of the errors that may arise in the interpretation of the results by the ordinary methods of analysis.

The classical method of procedure consists essentially in moving a known weight $w$ through a distance $d$, thus causing a transverse shift of the centre of gravity of the whole vessel of amount

$$X = \frac{w \cdot d}{W}$$

where W is the displacement at the time of the experiment. The angle of heel, $\theta$, due to this shift is obtained in terms of its tangent, by measuring the swing of a long pendulum of known length; two measurements are made, when the vessel is heeled to port and to starboard respectively. The vertical position of the centre of gravity is then derived from the metacentric height given by the formula

$$m'' = \frac{X}{\tan \theta},$$

the mean of the two values being taken.

This relation implicitly assumes that M is a fixed point for the range of inclination from 0 deg. to $\theta$ deg., or that the sides of the vessel in the region of the water-line are arcs of circles. If the stability is of large or of moderate amount the assumption is sufficiently accurate; but for low values of $m$ it is not so. If $m$ is zero, it would require an infinite inclination to satisfy the relation, and if $m$ is negative, an obviously absurd value; whereas experience shows this is not the case.

§3. Professor Scribanti, relying on both theory and experiment, advanced the following relation as a solution:—

$$\tan^3 \theta + \frac{2m \cdot \tan \theta}{\rho} - \frac{2X}{\rho} = 0 \quad . \quad . \quad (1)$$

where $\rho$ = B M, the metacentric radius.

The underlying assumption is that the vessel is wall-sided in the region of the water-line (and it also holds true if the sides are arcs of parabolas). The use to which he put this relation in his paper was to calculate the angle of heel due to a given value of X when $m$ is known. The solution of the equation for tan $\theta$ calls for a very advanced knowledge of algebra; however, in applying it to the inverse process of determining $m$, given $\theta$ and X, no such difficulty will be encountered.

§4. For the purpose of the following note the general problem of the inclining experiment may be stated as follows (see Figs. 1 and 2):—

Let

W be the displacement at the time of the experiment.
$\rho$ be the B M, or metacentric radius when the vessel is upright.
$m$ be the G M, or metacentric height when the vessel is upright.

Let

$\theta_0$ be the angle between the vertical through B G when the vessel is upright, and the initial vertical through $B_0$ $G_0$ (assumed to port).
$X_0$ be the transverse eccentricity of the centre of gravity causing the initial heel $\theta_0$.

Let

$w$ be the weight of the inclining ballast moved.
$d$ be the transverse distance this ballast is moved.
X be the consequent shift of the centre of gravity ($X = w \cdot d/W$).
$\theta_1$ and $\theta_2$, measured from the initial through $B_0$ $G_0$ to port and starboard respectively, be the angles of inclination caused by the shift of ballast.
$s_0$, $s_1$, $s_2$, corresponding to $\theta_0$, $\theta_1$, $\theta_2$, be the distances, measured on a horizontal batten, swung by a pendulum, length $l$.

W, $\rho$, $w$, $d$, $s_1$ $s_2$, and $l$ are known or determinate.
$s_0$, $\theta_0$ and $X_0$ may or may not be known.
With this information it is required to find $m$.

§5. The following three simultaneous equations suffice to determine $m$ in any case:—

$$\tan^3 \theta_0 + (2\,m/\rho) \cdot \tan \theta_0 - 2\,X/\rho = 0 \quad . \quad . \quad . \quad (2)$$
$$\tan^3 (\theta_0 + \theta_1) + (2\,m/\rho) \cdot \tan (\theta_0 + \theta_1) - 2\,(X_0 + X)/\rho = 0 \quad (3)$$
$$\tan^3 (\theta_0 - \theta_2) + (2\,m/\rho) \cdot \tan (\theta_0 - \theta_2) - 2\,(X_0 - X)/\rho = 0 \quad (4)$$

There are two main cases to be considered:—

(i) When $\theta_0 = 0$.
(ii) When $\theta_0$ has any other value.

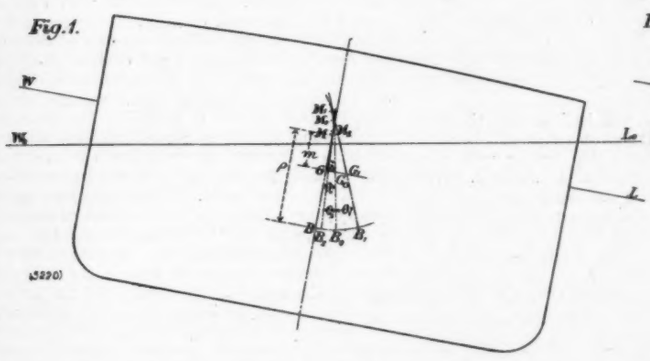
§6. Case (i).—When $\theta_0 = 0$ the vessel is necessarily in stable or in neutral equilibrium and the centre of gravity is in the plane of symmetry, or $X_0 = 0$. Either equation (3) or (4) is sufficient to determine $m$, and $\theta_1$ should by sympathy be equal $\theta_2$; thus the mean of the two values of $m$ so found may be taken.

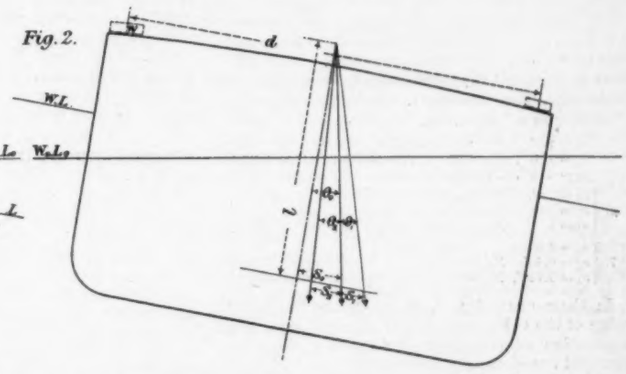
There follow some examples of the application of this method, and a comparison with the results obtained by using the classical formula. In these and all the other examples given in this article the experiment is assumed performed on a vessel of 4,000 tons displacement, having $\rho$ = 16 ft. when upright, by moving 2.5 tons of ballast 40 ft. across the deck, X being 0.025 ft.; a pendulum 20 ft. long is used to measure the angle of heel:—

| | | |
|---|---|---|
| 1. $s_1 = 0.5'$, | $m = 0.995'$, | $m'' = 1.0'$. |
| 2. $s_1 = 2.0'$, | $m = 0.17'$, | $m'' = 0.25'$. |
| 3. $s_1 = 2.925'$, | $m = 0.0'$, | $m'' = 0.1712'$. |

(where $m''$ is the value of the metacentric height obtained by using the classical formula: $m'' = X/\tan\theta$).

The error involved in using the classical method is negligible when the stability is great or moderate, but may be quite appreciable when the stability is small and accuracy is consequently of greater importance.




§7. Case (ii).—This includes several different cases where the vessel has an initial heel, viz.:—

(*a*) When the centre of gravity of a vessel is unsymmetrically placed, *i.e.*, is not on the centre line.

(*b*) When the vessel would be in unstable equilibrium with the centre of gravity on the centre line if she were upright.

(*c*) When as in (*b*), but having the centre of gravity unsymmetrically placed.

(*d*) When it was not definitely noted at the time of the experiment whether the vessel was upright or not.

All these cases can be solved in the same manner by the use of equations (2), (3) and (4), but there are one or two points that call for special mention.

§8. In the first place, the vessel is in all cases initially in stable equilibrium, even when it would be unstable when upright, and, with certain limitations, inclines about this initial position. Again, the angle of heel produced by a given shift of ballast will usually, but not necessarily, be greater when the vessel inclines towards the upright than when the inclination is outwards—*i.e.*, usually $\theta_2$ is greater than $\theta_1$.

If a vessel coming under class (*b*) is inclined inwards by a shift of ballast, sufficient in amount to make the vessel heel beyond the upright—making $\theta_2$ greater than $\theta_0$—she will continue to heel towards that side until $\theta_2 = 2.\theta_0 + \theta_1$, behaving as though inclined about a second position of stable equilibrium on the opposite side of the upright. If this occurs, the metacentric height is at once determinate, for

$$\theta_0 = \tfrac{1}{2}\,(\theta_2 - \theta_1)$$

$$\tan \theta_0 = \tan \frac{(\theta_2 - \theta_1)}{2},$$

* See ENGINEERING, vol. lxxvii, pp. 459, 763, 801, 860.

and can, therefore, be expressed in terms of $\tan \theta_1$ and $\tan \theta_2$.

Also, Professor Scribanti has shown that for an unstable ship $\theta_0$ and $m$ are connected by the relation

$$m = -\frac{P}{2} \cdot \tan^2 \theta_0$$

as can readily be deduced from equation (2) by putting $X_0 = 0$.

These considerations suggest a ready, but decidedly risky, method of inclining an unstable ship; it should, however, be avoided, as the vessel will roll with an unpleasant lurch after passing the upright position to an inclination far beyond $(\theta_0 + \theta_1)$, which may even be dangerous, before coming to rest. The amount of inclining ballast, rather, in a ship of doubtful stability not initially upright, should be arranged so as not to bring the ship near to the upright position.

§ 9. With regard to the general procedure, it is better, if possible, to measure $s_0$ (tan $\theta_0$), for this will save a large amount of complicated algebra, although a correct solution can be obtained without doing so.

It is not evident from a mere inspection of the measurements made under which group the vessel falls as regards stability; but the following examples have been selected to illustrate the various possibilities:—

4. $\begin{cases} s_0 = 2.0', & \text{to port} & \tan \theta_0 = 0.1. \\ s_1 = 4\frac{1}{2}'', & X_0 = 0.108', & m = 1.00', \quad m'' = 1.33'. \\ s_2 = 5'', & X_0 = 0.108', & m = 1.00', \quad m'' = 1.21'. \end{cases}$

It is to be noted that difference between $\theta_1$ and $\theta_2$ is genuine, both leading to the same value of $m$. The error in $m''$ is serious.

5. $\begin{cases} s_0 = 2.0', & \tan \theta_0 = 0.1. \\ s_1 = 1'\,6'', & X_0 = 0', & m = -0.08', \; m'' = +0.333'. \\ s_2 = 6'\,0'', & X_0 = 0', & m = -0.08', \; m'' = +0.083'. \end{cases}$

6. $\begin{cases} s_0 = 2.0', & \tan \theta_0 = 0.1. \\ s_1 = 10\frac{1}{2}'', & X_0 = 0.028', \; m = +0.2', \quad m'' = +0.572'. \\ s_2 = 1'\,8'', & X_0 = 0.028', \; m = +0.2', \quad m'' = +0.3'. \end{cases}$

7. $\begin{cases} s_0 = 4.0', & \tan \theta_0 = 0.2. \\ s_1 = 0.63' & X_0 = 0', & m = -0.3', \; m'' = +0.8'. \\ s_2 = 1.742', & X_0 = 0', & m = -0.3', \; m'' = +0.29'. \end{cases}$

In these examples $m$, of course, is the correct value of the G M, and $m''$ that obtained by a blind application of the classical formula; the errors involved are obviously appreciable, even when the vessel is stable, and may be very serious if the vessel is unstable. In all these cases the correct value is smaller than that derived from the classical formula. In wide shallow vessels, however, $m''$ may possibly be less than $m$.

§ 10. It only remains to emphasise one or two points. It is not necessarily correct to take the mean of the readings in evaluating $m$. The minimum amount of water ballast consistent with safety can be used without impairing the accuracy of the results; it is even unnecessary to trim the vessel upright. In this manner another possible source of error may be avoided. But it is also evident that if the usual method of analysis is adopted it is essential that sufficient ballast should be on board to give a moderately large metacentric height; certainly not less than 1 ft. in the case of the vessel used as an example.

## THE IRON AND STEEL INSTITUTE.

As stated in our last issue, the first paper taken at the meeting on Thursday morning, the 20th inst., was the one entitled "Notes on the Present Knowledge and Practice in regard to the Briquetting of Iron Ores," by Mr. Guy Barrett (Ebbw Vale) and Mr. T. B. Rogerson (Glasgow). It was read in abstract by the former, and we reproduced it fully on page 299 *ante*.

### NOTES ON THE PRESENT KNOWLEDGE AND PRACTICE IN REGARD TO THE BRIQUETTING OF IRON ORES.

The discussion was opened by Mr. Cosmo Johns, who stated that he had read the paper with great pleasure. It was a most useful contribution and very well written. Its title should read "Notes on the Present State of our Knowledge . . ." The bibliography given by the authors was an admirable one. The Technical Committee for Ores, Fuel and Refractories should, he thought, be proud that it had brought forth such a report, which will prove of benefit to manufacturers. So little was known of the stability relations of the oxides of iron, and these were so important in practice, that if any fresh light could be added in this respect it would be advantageous to the industry and also to science in general. The nature of the iron ores came in also for consideration, and there were various grades of fine ores of different structure and chemical composition. Some low-grade British ores were difficult to agglomerate; the authors had referred to various difficulties which occurred, and if they were able to give the results of further experiments in agglomerating practice, and discuss further the physical and chemical states of the ores, manufacturers would be their debtors still more.

Mr. W. H. Hewlett, who followed, expressed the hope that the paper would facilitate the task of the works which had small ores to deal with. In the ores a large portion was small, and the separation of the large from the small involved cost, and some simple method devised for dealing effectively with the small would be welcomed. Simple pressure was not sufficient, as the briquettes disintegrated with the weather, and some arrangement had to be made for calcinating. Calcination by the waste heat from blast-furnaces could be resorted to. He also referred to future papers of the Technical Committee, such, for example, as dealing with the generation and distribution of power at different works by means of producers and electricity. The Ores, Fuel and Refractories Committee had in hand a very wide range of questions. Its report was not yet ready, and it would be postponed to a later meeting.

Mr. C. H. Ridsdale said he had read the paper with great interest; it was one of great importance to this country, where the dealing with small crumbly material had been a bugbear. When briquetting or nodulising was undertaken, the whole of the trouble was not, unfortunately, overcome. And in this he referred to chemical points, the first being the behaviour of the briquetted product in the blast-furnace. Whether the ore was peroxide or carbonate, or, again, magnetic oxide, if it became reduced by solid carbon anywhere near the hearth, only 30 per cent. of the effective heat of the coke was utilised in the furnace. The ore had to be reduced in the upper part of the furnace by the carbonic oxide gas, so as to obtain efficiency. Sintering and nodulising seemed to give the hardest products. He (the speaker) was struck by the authors' remark on flue dust, where they said that they did not find benefit from the particles of coke which the flue dust contained. He thought the reason was largely due to the condition of the oxide that was formed. He had tried several years ago how far he could go with magnetic oxide ores in the blast-furnace, and gradually increased the burden up to the point that 12 cwt. of every ton of pig-iron produced came from this magnetic oxide ore. That was 63 per cent. of iron, and he thought he would have had a lower coke consumption and a greater yield, but the yield did not increase. When he had reached 12 cwt. out of every ton of pig-iron produced this was about the limit. In fact, about 5 cwt. was about as much as was advantageous. This bore out what he had said with regard to the condition of the oxide. With regard to the using up of the flue dust, this seemed alluring. The finest material was nearly always more siliceous than the good lumpy part of the ore. He questioned whether it would pay to put down a plant for dealing with the available flue dust, as this was generally low in quantity. One way he had not noticed mentioned, and he would like to refer to it; this was to the effect that some time ago he had acted as an adviser in a matter which had nothing to do with briquetting, but with a question of disposal of the flue dust, and he suggested adding this to the charge of crushed coal in the coke ovens, the object being simply to give spongy iron disseminated through the coke. The quantity was about 120 tons of flue dust for about 2,000 tons of coal. It was no detriment to the coke; the flue dust would not absorb much carbon, it contained practically enough carbon for its reduction; it answered, but was unsuccessful in that the traffic conditions did not allow of mixing the small quantity of flue dust with the larger quantity of coal. There was, further, a large amount of spongy iron in one batch of coke and none in another batch, leading to irregularity in the working.

Mr. Greville Jones congratulated the authors on their paper and also on their list of references. The sintering process was the one which he should probably adopt. He thought that, from information given in the German technical journals, Germany used a certain amount of sintered ores in the furnaces, and this did not affect coke consumption at all. There was no comparison, he thought, between sintered ores and the magnetic oxide ores mentioned by the previous speaker. Sintered ores he had seen were porous, and there seemed to be no difficulty in regard to reduction. He (the speaker) questioned the advisability of putting flue dust in the coke ovens, it would affect the brickwork of the ovens, and with regard to the danger of the dust getting in the hydraulic mains he was afraid that the cure would be worse than the disease.

Professor Louis said he disagreed with the authors on a few points; he objected to their classification and disliked the authors' method of reference to briquetting with or without a binder. He (the speaker) had heard of purple ore briquetted in two places, one using clay as a binder and one no binder at all. The briquette with clay contained 64.7 per cent. of iron and 5.2 per cent. of insolubles; the one without binder contained 67.4 per cent. of iron and 1.6 per cent. of insolubles. The ores were obviously of very different commercial value, and this showed that a system of classification should be used to bring out the differences. Subdivisions should be made into different types of binder, stating also whether acid or basic. The authors had stated that the iron was converted into ferric oxide. He (the speaker) had had twenty years' experience in the matter of magnetite briquettes, and had in no case found the whole magnetite converted into ferric oxide; he always found sufficient magnetite left in the briquettes to affect the magnet. He agreed with the authors' conclusions. He preferred briquettes made without pressure, even heated afterwards, to briquettes made with pressure and then heated. Troubles arose in briquetting and burning the briquettes when dealing with highly hydrated hematite, but they disappeared when using the nodulising and sintering methods, and he thought those were the best methods. He did not quite agree with the authors in condemning the nodulising process; when the temperature was exactly right he did not know of any other process which gave better results than the nodulising, and he was inclined to think that it should not be discarded without further experiments.

Mr. T. B. Rogerson said he had worked at briquetting for 25 years, the briquettes being, first, hand-made, dried in kilns and then burned, and he still made these and found them more reliable than any other kind. As a binder, he used a little aluminous ore to allow the briquettes to stand to a certain height in the kiln. They stood up to the work in the blast-furnace, but the work of making them was rather heavy. The difficulty was in getting the temperatures right. He used nothing but blast-furnace gas. When this was very hot the material would stick to the sides of the noduliser, and when very cool only dust was obtained. If the temperature could be kept at one correct point the material could be got right. He tried putting blast-furnace dust in the material to briquette, but when burning it ran into a solid mass, and it was very difficult to get the mass out. He still believed the old process he referred to was a first-class one, nodulising also was good, but, he repeated, the temperature had to be kept right.

Mr. S. Williams confirmed Mr. Ridsdale's experience as to the addition of flue dust to the coal in coke ovens, and questioned whether we should get any flue dust to use in the future.

Mr. H. Bumby stated that for a process to be successful it was necessary to study the chemical composition of the material; a process successful with aluminous ores would not suit other ores. In the matter of briquetting the Germans had learned

from us. The Schumacher process, for example, was an elementary matter, which was known to all years ago, and, like others, it had no right to be known under the German name. The product, the authors had said, should resist a temperature of about 900 to 1,000 deg. C. without disintegrating; he (the speaker) had found better results in calculating the pressure in the upper part of the furnace and then heating the briquette at a temperature of 700 to 800 deg. If the briquette were heated at this latter temperature at a pressure equal to that which it would meet in the reducing portion of the furnace, it would stand. The subject of reducing sulphur in briquetting and nodulising was an important one in the dealing with pyrite residues; in regard to the reduction of sulphur, this only went on at a relatively moderate temperature, and took place after the briquettes were burned in the sintering kilns, when the air was passing over the burnt briquettes at a low temperature comparatively, below redness. Variations occurred with pyrites of different analysis, and all the ingredients they contained were not reduced. In the matter of cost and fuel consumption, this would rather startle those who had not experimented with any so-called patent process, but others would quite see that a cost of, say, 1*s.* 6*d.* as quoted would in actual practice become 8*s.* to 9*s.* He continued that one could get specimens of nodulised ore quite suitable for the furnace.

Mr. G. Barrett, in reply to the discussion, said that in his experience 95 per cent. of the nodules worked better than the briquettes; the Gröndal briquettes were, in his experience, friable briquettes. In regard to the statement by Mr. Williams that we should have no flue dust, the better quality the ore, the more flue dust there was, and it was fuel recoverable as useful fuel. He added that the authors would reply in detail in writing for publication in the proceedings.

On the motion of the chairman the authors were awarded a hearty vote of thanks for their contribution.

### New Experiments on Shock Tests and on the Determination of Resilience.

The next paper taken dealt with "New Experiments on Shock Tests and on the Determination of Resilience," contributed by Mr. G. Charpy and Mr. A. Cornu-Thenard. We begin the reproduction of this paper in full on page 346 of our present issue. It was read in abstract by the secretary.

The discussion was opened by Dr. Rosenhain, who stated that the paper contained a large amount of carefully-detailed work which needed careful study. It put the impact test on notched bars on quite a different level from that which it had hitherto occupied. The test was of value, but he found a range of inaccuracy in the results it gave, and it was necessary to average the data on a large number of test pieces. The work described by the authors in their paper required to some extent a modification of that view; variability in the results should be ascribed to variety in the steel itself. There was, however, no cause for alarm. It was true, as proved by the paper, that the test was not responsible for the variety in the results. It should be remembered, however, that the test was a very sensitive one. In reading the paper there might be a tendency to exaggerate the importance of the relatively small variations. It emphasised that when the variations were large, of probably 20 per cent. to 50 per cent., then a result was obtained which meant something important and very definite. One had yet to find examples where a piece of steel behaved badly in practice after giving good impact figures. If the heat treatment improved the steel under the impact test it proved that there was something wrong in that steel originally. The main importance of the paper was that it showed the possibility of getting perfectly uniform results on machines as different from each other as were the Guillery and the Charpy machines. But he (the speaker) was compelled to add that he did not like the term "resilience"; it had a definite meaning. The Charpy machine gave the work of rupture. It was a pity to use the word "resilience" and invent a new meaning for it. One might use "work of rupture," "rupture," or "impact figure." The Institute was indebted to the authors for having, by their contribution, placed the whole question of the impact test on a sounder basis.

Professor Arnold thanked the authors for their valuable data, which would be found of the greatest possible use. He agreed with Dr. Rosenhain that the term "resilience" was a quite misplaced term. The authors had stated that their work was to define the method for carrying out resilience tests and to investigate the connection between the results of these tests and the behaviour of metallic parts in practice. Professor Arnold confirmed the fact that if these tests were to be of value they had to correlate the results with the results obtained in practice, otherwise they would be of little use. On the other hand, the authors had said they proposed to reply in the future to the question as to what was the practical purport of such tests; in other words, said Professor Arnold, after carefully going into the tests and pointing out their value, they were not prepared to say what they meant in actual practice. Professor Arnold then sketched on the blackboard a machine which had been devised in Sheffield which, though very simple, had proved useful, in which the alternations were 600 per minute. He had found that the type of steel suitable for Admiralty forgings endured 300, generally 340. He showed on his sketch the points where fracture took place under different conditions, adding that for two steels having the same composition and the same tensile strength, one could be found much better than the other under his test. He has compared this with the shock test, and when the steel was bad his and the impact machines gave the same results.

Mr. R. E. Allcut said that the authors had stated that in practice it sufficed that the average relative divergence in a series of determinations remains below 5 per cent.; this was a rather large figure, and he thought others would account for rather less than 5 per cent. They had also stated that they had employed unnotched bars in such a way as to limit determination to a well-defined bend, so that the small local irregularities which may subsist from one point of the metal to another did not interfere to any appreciable extent. He (the speaker) hardly thought this was at first sight satisfactory as a method of calibration, and asked whether a definite angle of bend had been obtained. The initial bend was likely to differ from the final one—there occurred a slight spring in the material. The authors' question as to whether in the treatments the superficial layers of the test pieces may not have undergone modifications influencing the impact test results obtained, was, he thought, an important point for consideration.

The authors, he added, had taken a large ingot and had chosen their specimens from the good part of the ingot. He emphasised the careful preparation of the specimens. It was quite possible to mar an impact test by preparing the specimen without due care. With regard to homogeneity, he (the speaker) thought the Brinell number to be a rather coarse indication, and would suggest the scleroscope test on the portion of the test piece immediately surrounding the notch before and after fracture. He was surprised to see the authors mention the use of "punched specimens," and took it for granted that drilling was resorted to. In regard to artificial variations, these were shown by the impact tests and not by the Brinell test, and probably not by the tensile test. There was ample evidence in practice to show that that was the case. The time element also came in. He asked whether the foundation of the machine had any influence on the results obtained, and whether the large one and the small one were bolted down to the same foundation. Also whether there was means of finding out whether the mass of the foundation influenced the results. It was a pity, he added, that there were two variables in the matter of the notches. There were round, angular and square notches and different depths of material, therefore two variables. It would be advisable with the different notches to have the same thickness of metal beyond them.

Mr. H. H. Ashdown, dealing with the application of the test to practice, said the authors introduced several important points, namely, the great influence which mechanical operations, on the plastic metal and under varying conditions, had on the impact tests. This was a point which could be noticed repeatedly in works practice, and one of considerable importance at the moment to steel manufacturers and forge masters. There were certain high-class forgings which were subject to impact testing, and which, although otherwise giving remarkably good mechanical tests, failed absolutely under the impact test. It was agreed that other factors also might have this influence, but after guarding against these possible causes of failure and embracing all advantageous treatments to the subsequent forgings, the failure under impact could often be attributed to the initial forging stages. Excessive heating or sustained soaking at high temperatures were fruitful causes of failure. It was also true, as stated by the authors, that under ordinary conditions of microscopic examination there was nothing appreciably different between the structures of the material giving both good and bad impact tests. Dr. Rosenhain had called attention on a former occasion to the fact that it was prejudical to anneal steel forgings at temperatures bordering on the change-point range. The effect on the impact test was equally bad when steels, after quenching, were tempered at similar temperatures, and, again, very poor results were obtained if forgings were maintained for long periods at even comparatively low tempering heats.

Mr. E. H. Saniter found the object of the investigations to have been very fairly attained, and the paper greatly advanced our knowledge of impact testing. The greatest care had been taken to obtain concurrent results. Several points were not clear, the punching, for example, and the unit of area to which the impact figure applied.

Dr. W. H. Hatfield greatly appreciated the paper. We were interested in all forms of impact testing, and the Charpy, Izod, and other types of testing machines might be taken to give reliable results. If the test piece were well prepared and notched with great care, very concordant results were obtained. Mr. Charpy had shown that the energy of the blow did not affect the energy absorbed by the specimen. He (the speaker) had made tests with the Izod machine and had obtained a perfectly straight line. The results were concurrent with the large and the small machines. He added that the impact test was a combination of the shock test and bending test.

Mr. J. S. G. Primrose said the paper showed remarkably concurrent results obtained with different machines. The Guillery machine was not as described in the paper, but was a rotary tup machine, actuated by a handle in the same way as a motor engine was cranked up, and was able to carry out tests at a rate which the other types of machines mentioned in the paper were not able to attain. He (the speaker) considered that a knowledge of the remarkable results contained in the paper would bring about a feeling of much greater reliance on the value of the transverse impact test as applied to steel. The most important point from the practical standpoint was the possibility of attaining such close agreement in the results as were recorded by the authors. It was, further, of great value to know authoritatively that two such different types of machine as the Charpy and the Guillery were capable of giving strictly analogous results, which was no doubt due to the similar method of fracturing the bar. In the Guillery machine, which he had been privileged to use for some time, the anvil absorption of energy was eliminated, and did not require the test piece to be fastened to the block, wherein it differed from the Izod machine, in which the pendulum bent the bar at the anvil vice grips before it fractured the test at the notch. A further advantage of the Guillery rotary tup machines lay in the fact that they were completely enclosed and therefore quite safe to work. He was of the opinion that the Institute should recommend the adoption in this country of a standard size of test bar to be employed in the impact test, and also that the size and contour of the notch should be fixed, and not allowed to be variable as in present practice. The impact test appeared to him to be a most valuable test in practice,

since it was able to show up in many cases the type of metal which, although able to comply with ordinary standard specifications as to tenacity and tensile ductility, would fail in working or prove fragile in a structure under transverse stress. He proposed communicating to the written discussion some results of recently made tests in illustration of this point.

Dr. F. Rogers, who followed, criticised the preparation of the specimens as given by the authors, and said it would be difficult for anyone to reproduce these specimens. He also thought the authors should have used a smaller ingot. In working with bars taken from an ingot of about 20 cwt. to 40 cwt. he had always been able to obtain shock test results agreeing well within 10 per cent., and even within 5 per cent., on an untreated bar, and within 3 per cent. on a treated one. In the matter of the use of the word "resilience" he agreed with Dr. Rosenhain; we had the word "toughness," which could be used. In regard to the effect of the foundation, a point which had also been raised, he (the speaker) added that he had a machine with a suspended anvil, so that the amount of energy transmitted to the anvil was also recorded; it was very small. The correction for this in the result did not amount to a variation of as much as 3 per cent. in a single bar. He though Mr. Charpy was perhaps too easily content with the chemical analysis of his bar. The variations in the sulphur percentage, 0.014 down to 0.010, were too great variations. He continued that he preferred to use a bar rolled down from a comparatively small ingot.

The chairman, in moving a vote of thanks to the authors, stated that the members could reply further in writing to the various points raised.

### NOTES ON THE HEAT TREATMENT OF GREY CAST-IRON.

This paper, by Mr. J. E. Hurst (Acton, London), was next taken. It was read in abstract by the author. We reproduce it in full on page 330. It deals with the question of the behaviour of cast-iron when subjected to heat, in so far as it concerns the deterioration of cast-iron cylinder components—the liner, piston and valve chambers. It forms Part I of a series which the author intends to put before the Institute.

The discussion was opened by Professor H. C. H. Carpenter, who said the subject was a very important one, but all too briefly dealt with in the present contribution, and he would welcome the following one. He (the speaker) felt convinced that the author knew much more than he had stated. He had said that the greatest enemy to cast-iron as a material for the construction of Diesel engines was the element phosphorus, and that many difficulties in connection with cracking were removed when the phosphorus was brought down to the lowest possible limits. This was important, and he would like to know what was, in the author's opinion, the percentage of phosphorus which would fulfil that condition. He had said that the piston head might reach a temperature of 900 deg. to 950 deg. C. Now, the melting-point of the phosphide eutectic was 953 deg., therefore when the temperature of 950 deg. was reached the main cause of cracking when the phosphorus was high was due to the melting of the eutectic. Was the temperature of 900 deg. to 950 deg. an experimentally determined figure? There were much higher gas temperatures than that reached in Diesel engines, probably up to 1,600 deg. The temperature of the gases was very much higher than the figure given in the paper. With regard to the change in the condition of the carbon alluded to by the author, there was no doubt that the condition of the carbon changed; some might be precipitated and some be redissolved, stresses would follow, and he (the speaker) was not surprised that fracture should be due to this cause. It was interesting to note, he concluded, that in spite of the gas burned in the cylinder being strongly oxidising, the author found no indication of oxidation of the carbon and silicon contents.

Mr. E. Adamson, who followed, said he realised that this was a field for research. The author had referred to the growth of cast-iron, and he (the speaker) was rather inclined to think that a certain stretch occurred before the growth commenced. The paper mentioned that it would appear that a temperature between the limits of 750 deg. and 900 deg. C. had little influence on the rate of decomposition; this scarcely agreed with what was found by other experimentalists, but, on the other hand, there were so many variations in the tests of cast-iron recorded and in the results obtained, that it was necessary to know all the conditions before arriving at a decision. In the matter of re-absorption, when cast-iron was chilled at any given temperature stresses were set up, and one could have carbon in solid solution, in quantity depending upon the temperature at which quenching took place. He was glad that the author took the view that the swelling of the graphite plates left a vacuum.

Mr. Young questioned the carbon contents and their bearing on the occurrences. The author's sulphur and phosphorus percentages did not, he thought, refer to practical types of cast-iron; they were nothing like what the Diesel engine makers aimed at. The author's Table III did not give the sulphur content, and this was an important part of cast-iron composition, and he had arrived at the carbon percentage by colour. He (the speaker) further questioned various points in the analyses and microphotographs put forward by the author.

The meeting was continued on Thursday afternoon, when two papers by the Technical Committee No. 3, for Steel and its Mechanical Treatment and Ferro-Alloys, were read and discussed. We reproduce them on page 344 of this issue.

The first one was entitled

### PRELIMINARY REPORT OF THE METALLURGICAL SECTION OF THE COMMITTEE.

It was read by Mr. E. H. Saniter, who stated that the object of the meeting was for discussing and tapping sources of information, with a view to completing the present inconclusive report. One firm, he said, had suggested preparing a standard design of furnace, and offered their plans. Any firm sending in their plans of furnaces having a good output would aid the committee in considering the various points, such as that of a standard furnace.

Mr. Alleyne Reynolds, who opened the discussion, emphasised the opinion expressed in the report with reference to the lay-out. British practice was inferior to foreign for a reason which he thought redounded to the credit of the British works. A British works had to extend and to put down a new plant on land costing 1*s.* per square yard. An Austrian works for corresponding extensions obtained the land most cheaply, and were allowed free use of the streets for conveying all their pig-iron from their blast-furnaces to their steel-making plant. The goodwill conditions which existed in England rendered comparisons illusory. Mr. Reynolds also stated that in the Austrian practice the ore was charged into the furnace before the pig-iron. He repeated that, taking all things together, all comparisons between the British and the foreign practice made it impossible to draw general conclusions.

Colonel Belaiew, who followed, said that Professor Grymalloff, of Petrograd, had brought together a number of original plans and best designs of furnaces giving the most favourable output. A large amount of work had been done of late in Russia in the matter of improved open-hearth furnace plant; he mentioned also the name of Professor Pavloff in this connection, and suggested that these gentlemen should be approached with a view to supplying the results of their work to the Institute.

Mr. Cosmo Johns stated that he was intensely disappointed with the report; he had never seen anything so immature and fruitless, and added that in the early years of his experience in steel-making all the problems had been worked out. Justice should have been done to what had been achieved in practice. The list of questions had been sent out by the committee to certain people; others who could have answered had been left out. He had not received a list. Mr. Cosmo Johns added that he was not surprised to find that the answers received were inadequate, since people who knew much about the subject had been left out. (Here the chairman interposed that Messrs. Vickers had been asked to reply to the queries, but that they had not done so.) He (the speaker) had not personally received the list, and that, he added, was one disadvantage of dealing with a very large firm. He thought that all the required information, on the size of the furnaces, among other points, could have been obtained by consulting foreign literature, and the committee could have made a bibliography of this. Questions as to design and foreign practice were obtainable. In regard to the statement to the effect that the $CO_2$ in the producer gas should not exceed 5 per cent., but that it could rise to under 10 per cent. when it was necessary to have an abundant and regular supply of gas, this had been written, he thought, under a misapprehension, for the percentage was decided by the properties of steam and air, and the best work done in this and in other points was all recorded in the Institute's proceedings. He strongly objected to the raising in the report of the wages question; he did not consider it wise to deal with such a subject, especially in the present time of war; and, besides, the Institute had always kept wages outside its discussions. There was in existence an association for the adjustment of wages. He could not accept the figures given, as no authority had been quoted. It was stated that the labour at the furnace cost here about seven times as much as in Germany; such might be the case, but he wanted to know the authority for the statement. He suggested that the report be not published, but be held in the light of a confidential one and be taken back by the committee for further consideration, since it did not do justice to the names of the men given. As careful a résumé as possible should be added on the state of our knowledge of the industry abroad. Then when a bibliography was available and the points dealt with could be checked, a meeting could be held to see how we could improve our manufacture. But, added Mr. Cosmo Johns, when all the circumstances were known, he thought it would be recognised that the British open-hearth practice was not in such a desperate situation.

Mr. T. B. Rogerson said he had had experience in America, and he believed our open-hearth practice here was now mechanically as good as the American. The furnaces, the producers, and also the lay-out were all as good. The difference in the matter of cost came from the fact that we had here a short week, whilst in America they had a long week. He stated an instance of an American plant where there were four furnaces of 50 tons to 60 tons each; two leading men and four other men, six in all, were in charge of those four full furnaces. This made a great difference when compared with our practice. The American furnaces he referred to ran seven days per week. If we had the same practice here we could naturally produce more than we now did. He, however, did not think the American output was as high as 50 per cent. above our own.

Mr. W. Simons, speaking as a member of the committee, said that the object of the paper had been to stimulate discussion. Mr. Cosmo Johns had been very critical, but he had not assisted in any way by his remarks. The views in the report were those of men who had given great attention to the German practice. One point making for the greater German output was that of the shallower German baths, from which three and four charges were made per day of 24 hours. A German 35-ton furnace produced 1,000 tons per week, but it would be found that that German furnace was probably equal to a 50-ton British furnace. He (the speaker) knew of a Silesian 35-ton furnace which was very similar to a 50-ton furnace at Sheldon. The Silesian furnace produced 700 tons per week, the English one 600 tons, but it should be noted that in the Silesian furnace they tapped the last cast at 4 a.m. on Sunday morning, a point he referred to simply to show how the difference in output was arrived at. The question of using a shallow bath, or a deep bath, was an useful one to be discussed. When charging with cold metal, a shallow bath might be advantageous. He thought that elsewhere more care was given to the actual work of the furnace, and, further, that we in this country did not pay sufficient attention to the quality of the pig-iron required. In Germany attention was concentrated on the production of the best pig-iron for open-hearth

practice. There were very few cases in England where that could be done, *i.e.*, the making of an ideal pig-iron for open-hearth practice. In our north-eastern district, with the raw material available there, it was difficult to make an ideal pig-iron. Moreover, with perhaps one or two exceptions, he thought the Germans had a better quality of refractory material than we; they could charge immediately after tapping, whilst we had to examine the furnace after tapping each time. In regard to labour, he certainly thought that question did come in, but the committee was not regulating labour, it was simply trying to arrive at the reasons for the differences in the output. When in this country we fixed a tonnage rate we immediately obtained an increased output, and the men were also earning more money. He felt sure that labour had more to do with the difference of output between British and German practice than anything else.

Mr. Greville Jones, who followed, referred to the Russian engineer, Pavloff, who had published designs of continuous furnaces. The output of a furnace depended upon many things. In America and in Germany the pig-iron was low in silicon, and that helped in the obtaining of an increased output. In Germany pig-iron was manufactured of different qualities, and the open-hearth furnace in Germany was an auxiliary to the Bessemer converter. That might be a reason. The Germans used more scrap. He remembered a place in Germany where, at 6 a.m. on Sunday, the last charge of a furnace had not yet been tapped, and that furnace had made 1,000 tons of steel in the week; the gas was never cut off from it. He was of opinion that if we could keep the gas on, as in Germany, over the week-end, we could produce the same quantity of steel as the Germans. A German 25-ton furnace had the same length as an English 60-ton one. In regard to producers, good practice would require keeping a chemist on the job continuously taking samples of the gas. He remarked that it was extraordinary that out of the same quality of pig-iron it was possible in British steel works to get heats out quicker on a Friday, especially if there was a football match on the following Saturday. British works were certainly making at the present time steel of a better quality than that now made in Germany. He (the speaker) did not agree with the remarks that had been made as to refractories, ours were as good as the others. Possibly the Germans got better results by pressing their silica bricks; they would perhaps last longer by being a solid pressed mass. The question of obtaining suitable pig-iron for steel works depended on local conditions. Germany bought all sorts of ores and mixed them together; this helped output. Here local people used their local ores.

Mr. D. Sillars thought that the attack which had been made on the report was rather an unfair one. The report was simply a synopsis of the replies which had been received by the committee. It was difficult to give an abridged report, and he suggested that one way out of the difficulty would be to publish the original replies received. There was no doubt that in Germany they started working with a better raw material, with a better ore mixture than we, and they could produce at a low cost a better quality of pig-iron. It was difficult to keep the $CO_2$ low in the gas. The constant presence of the chemist at the producers referred to by Mr. Greville Jones would not suffice to keep the $CO_2$ down; suitable fuel must be used for making the gas. If there was a depth of only, probably, 18 in. to 3 ft. of fuel above the blower, one could not obtain a gas low in $CO_2$. In Germany there was 6 ft. of coal in the producers, of which about 4 ft. was incandescent, and the gas had only 2 per cent. of $CO_2$. In this country we did not make the best out of our coal, and he questioned whether it would not be possible for the best coal for gas-producing to be taken to those places where gas was made, and to take the best coal for coke-making to other districts where they had bad coke. In regard to the suggestion made in the report that better-educated men should be induced to go in for steel making, he doubted whether better-educated men could be induced to work shifts at a furnace even for high wages, when they could earn about 5*l.* per week at less arduous occupations.

Mr. Alleyne Reynolds here asked the members of the committee whether information had been found in the matter of the selling price of phosphates in Germany and in this country. In German practice he thought much less account was taken of the phosphates than here.

Mr. Henry Crowe asked whether the members could give their experience as to the application of waste-heat boilers in open-hearth practice, and if this application resulted in economy and was advisable.

Mr. D. M. Maclay announced a paper on this latter point for a future occasion.

Mr. Walter Dixon said the committee had given their report; if it was incomplete it was due to the indifference of members of the trade, who had failed to answer the questions. He questioned whether the meeting was fair to the committee in discussing the report. The committee had been appointed, and had stated that here we had been producing less than on the Continent and in America. If in the latter countries they worked longer hours, they had a larger output. The output of the furnace per hour was that which was at the bottom of the investigation, and whether work was carried out during seven days or during five was outside the point. In the course of investigations in the matter of larger outputs it had been decided to bring the workman into the investigations; if the committee thought it possible to increase the output of steel above present figures, it might call in the men to assist. In regard to the work of the committee generally, the question was, Did the Institute want the inquiry, or not?

Mr. E. H. Saniter said the criticisms and suggestions would be replied to when they had been put before the committee. The report was only a preliminary one. The object of the inquiry was output rather than cheapness, and the question as to whether the phosphates from the slag came in to cheapen the steel did not arise. He noted with pleasure Colonel Belaiew's suggestion. The committee would welcome anything of a constructive nature which Mr. Cosmo Johns had to offer. The authorities of the committee were the replies received from 17 large firms, and the committee did not purpose to publish their names, so as to favour replies being made to the questions asked. The other remarks made were welcome; as to the question of using waste-heat boilers, this was not quite a germane subject, and there was the prospect of a paper on the point later on. With reference to Mr. Dixon's remarks, these were in the minds of the members of the committee, and the getting in touch with the workmen was a point that would be considered.

Mr. E. E. Wood here remarked that there were several ways of defining the size of a furnace, and suggested that the committee should inquire as to which was the best method to describe the size. (Mr. Saniter here stated that the paper mentioned that a convenient way was to give the tons per week per 100 sq. feet of bath area.)

Mr. A. Hutchinson thought it would be useful also if a paper could be got out based upon Mr. Cosmo Johns' suggestions.

The chairman said that the report which had been read was only a preliminary one, and it was hoped that the next one would be more complete.

The second report, which we reproduce on page 344, was entitled

### Preliminary Report of the Mechanical Section of the Committee.

It was read by Mr. A. J. Capron, who stated that it was a summary of the replies received rather than the expression of opinion on the part of the committee.

Mr. H. Crowe, who opened the discussion, said that Germany had been very generally stated to be ahead of this country in the mechanical parts of rolling mills, pinions, housings, and so forth; now, however, one could obtain as good or even a better mill here than in America or on the Continent. In regard to allotting the work to be done among different firms, he (the speaker) was afraid that each and all of them would want to roll the same large sizes. That the output in Germany was greater than in this country was not surprising, as the works had larger orders distributed to them, which they carried on without the necessity of roll changing—we could do the same here. He was surprised to see in the report that the question as to steam *versus* electricity had not been more fully replied to. Steam was not done with yet, and the low-pressure exhaust could be utilised in turbines, as was well known. But, he added, the ground covered by the report was so large that he would postpone his remarks on the various points.

Mr. H. J. Skelton was very glad to see that the Institute was now interesting itself in the economical side of manufacture. He had come to the conclusion many years ago that we were not backward in this country, but that much would be gained if the British engineers could be brought together and use their ability for the steel trade as a whole. It was gratifying to see the Institute taking action in regard to bringing together all the members of the trade, for unless these grave questions could be tackled one-half of the steel trade of this country would have no future. He had heard it stated that no works in this country could produce a girder equal in size to that produced in America, because here our mills had not the required speed; and this question of speed involved the gear, it meant, in fact, our putting down a new plant. He was interested also in the concluding remarks of the report, where the organisation of a Central Board for allocating orders was referred to. Some British works required new blast-furnaces, some new steel plants, but this involved a large amount of capital, and if this capital could not be obtained by steel makers individually it could no doubt be obtained by them as a whole, working on the lines followed by the American Steel Corporation. There were works which could better roll rounds than girders, girders better than other sections, and so forth, and what was needed was that the ability available in this country should be brought to one common focus. He was afraid that if we did not make a radical change in our methods we should stand a very poor chance in the markets of the world.

Mr. J. P. Bedson said it was remarkable to see that it had taken nearly fifty years for the Institute to express the idea that the cheapest way of rolling billets was the continuous system. If the suggestion that a Central Board be formed were adopted for allocating orders, then an opportunity would be afforded of putting down a continuous mill, leading to a large output in all sections, and where we now had to pay shillings per ton the price would be reduced to pence. The continuous system for this class of work was the one to adopt, and the steel trade should be subdivided.

Mr. Greville Jones stated that when British, American and German practices were compared together, it was only fair to compare them properly. In Germany one cogging mill cogged for four or five mills rolling various sections. With regard to the electric drive and the three-high mill, the question of the cost of the unit of current depended upon local conditions. He would not run his three-high mill electrically unless he could obtain the power at 0.15*d.* One firm in the report mentioned the price of 0.35*d.* per unit; this latter price would not suit his (the speaker's) case. In Cleveland they were going to discuss the question of gas engines for power and blowing. Judging from information which came from America, it was necessary to be very careful. One American works had put down a gas engine for all work at the blast-furnace, and electrified the rolling mills, when they found that they had to rapidly put down a steam plant, so as to run the works when the gas engine broke down. Gas engines, added Mr. Greville Jones, for generating power for mills, would not look after the peak loads. One had to proceed, therefore, most carefully and consider all points. It seemed to him that there was still a great deal to say for steam, and steam would always look after the peak loads. Some prices in the report seemed to him to be high, and he asked whether they included all charges, interest, depreciation, &c.; whether the price of 0.16*d.* given in the table in the instance where the steam was at 250 lb. per square inch, superheated to 640 deg. F., was correct. The Americans had been talking of a very high degree of superheat, and he would like

to have this confirmed. There was no doubt that our rolling speeds were low.

Mr. H. B. Toy appreciated the work of the committee. In America a mill had been erected for rolling rounds, and they had put down stores in connection with it, to stock the output; but these stores were never used, because the plant was able to produce at such low prices that none of the material ever went into stock. In this country we had to produce too many different sections. He agreed with a former speaker that we could manufacture in this country mills as up-to-date as those made in Germany. It was difficult here to persuade rolling-mill users to purchase the right sort of mill. He saw a sheet mill in Germany where breaking-down was done in a three-high and finishing the sheets in a two-high mill, the arrangement enabling the finishing of sheets at a higher temperature. The design of the rolls had a great bearing upon the output. He knew of instances where a section was produced in seven passes, where others required nine, and he had advocated in one case the use of rolls containing chromium, which produced a large quantity of rails without dressing and which were dressed in the mill housing when this was required.

Mr. A. J. Capron stated that the replies to the various points raised would be given by the committee.

*(To be continued.)*

## 32-TON ELECTRIC TRAVELLING COALING CRANE.

AT Glasgow Harbour there is probably as great a variety of appliances for the shipping of coal as is to be found at any port. Most of these appliances have been illustrated in ENGINEERING, and in view of the success of all the operations of the Clyde Navigation Trust—which establishes the ability and discrimination not only of the members of the Trust, men of great commercial engineering and shipping experience, but also of the technical officers—it is significant that one of the latest additions to the machinery of the port is an electrical coaling crane, which, by its own power, travels along the quay. This crane is illustrated on Plates XXVIII and XXIX. The view in the former plate is, in a measure, suggestive of the variety of cargo-handling appliances provided on the quays, and indicates also one of the advantages of the travelling jib crane, namely, its utilisation for other than coal-loading purposes, as it is shown building up a crane on a self-propelled barge. The other view shows the crane working on coal wagons.

The new Clyde Trust crane is capable of lifting 32 tons, and experience has proved that twenty 32-ton wagons may be handled per hour, or a greater number of smaller wagons. The crane travels on a rail track of 29 ft. gauge, and power is taken up from a bare copper cable, fixed in a trench alongside the track. The leading dimensions of the crane may be tabulated:—

| | Tons. | |
|---|---|---|
| Maximum working load ... ... | 32 | |
| Maximum test load for stability ... | 64 | |
| | Ft. | in. |
| Maximum radius ... ... ... | 47 | 0 |
| Total range of lift of block for general cargo ... ... ... ... | 100 | 0 |
| Total range of lift of block for coaling | 70 | 0 |
| Outreach from face of quay ... ... | 30 | 6 |
| Centre of jib-head sheave above cope... | 90 | 0 |
| Clear lift above cope of quay to bottom of cradle ... ... ... ... | 55 | 0 |
| Extreme tail radius ... ... ... | 14 | 0 |
| Clear height from cope to lowest revolving part of crane ... ... | 21 | 6 |
| Clear height under gantry ... ... | 15 | 0 |

The speeds of working with full load are:—

| | Feet per Min. |
|---|---|
| Hoisting ... ... ... ... | 50 |
| Slewing ... ... ... ... ... | 160 |
| Travelling ... ... ... ... | 60 |

The factors of safety are:—

| | |
|---|---|
| Structure and gearing ... ... ... | 8 to 1 |
| Hoisting ropes ... ... ... ... | 8 to 1 |
| Tipping ropes ... ... ... ... | 7 to 1 |

The gantry carrying the crane is built up of rolled steel sections and plates, and a clear space is left beneath the gantry for the passage of locomotives and wagons parallel to the crane track. Rail clips are fitted at each corner, in order to secure the crane to the rails during a heavy gale of wind. A hand rail is fitted the whole length of the gantry on the water side for convenience in shifting mooring ropes. For the support of the roller path and centre-pin bearing strong transverse girders are incorporated into the top structure of the gantry. For traversing there are 16 centre-flanged cast-steel wheels, mounted in pairs on boxes for distributing the load equally on each wheel. Two wheels on each side of the crane are fitted with spur rims, and are driven by a 50-brake horse-power motor through spur and bevel reduction gearing. The motor is mounted in an elevated position on the gantry, transmitting its power by horizontal and vertical shafts running in gun-metal bush bearings.

The general structure of the crane is clearly shown on the illustrations. It revolves on a roller path. The track on the gantry consists of a cast-steel ring, 24 ft. in diameter, built up of segments. The base of the crane consists of a similar ring, supported by heavy cross-girders and brackets, these girders having provision also for the centre pin. This centre pin is of forged steel bored through the centre for the passage of electric conductors, and is fitted in a socket carried by the cross-girders. This pin extends to the top of the vertical portion of the crane, where it is similarly secured to a gun-metal bush fixed to heavy cross-girders. The crane revolves round this centre-pin, on a ring of 56 live steel rollers running between two mild steel guard rings, and connected by radial rods to a spider casting around the centre pin. The rollers are turned conically, tapering from 14 in. diameter to 10 in. on the face.

The crane is revolved by means of a pinion carried on the end of a vertical shaft, which gears into a cast-steel spur ring, attached to the top of the gantry. At the upper end of the vertical shaft there is a 50-brake horse-power motor, which drives the shaft through the medium of one worm and one spur gear reduction. The motion is controlled by means of a foot brake fitted on the worm spindle. A special design of friction clutch is fitted to this gear, so arranged that in the event of excessive shock it will slip sufficiently to prevent injury to the gearing. Locking gear is also fitted to hold the superstructure in position during the prevalence of high winds.

The construction of the jib is well shown in the engravings. The connection between the jib and the vertical part of the crane is effected by large gusset plates. The jib-head sheaves are of cast-steel, mounted on a steel pin running in adjustable gun-metal bushes, and a ladder is fitted to afford access to the jib-head sheaves for lubrication purposes. The load is lifted on four parts best plough-steel wire rope winding on to a cast-iron drum driven by a 180-horse-power motor through the medium of three reductions of machine-cut double helical gearing. The hoisting motor is fitted with an automatic electric brake operated by means of a solenoid magnet, connected in such a manner that the brake is released directly the motor is started, and is applied directly the current is cut off, or fails for any reason. The brake can sustain the full load and bring it to rest directly the motor is stopped. A dashpot is fitted to prevent shock. In addition to this the load is controlled, when being lowered, by regenerative braking, the controller being specially arranged for this. The snatch block consists of two cast-steel sheaves, 26 in. in diameter, bushed with gun-metal and mounted on a steel pin. The block is designed to suit one of Armstrong's tipping cradles, and a separate crosshead, with ball-bearing swivel hook, is fitted for use with ordinary loads.

The tipping gear is arranged to work independently of the hoisting gear, and is under independent control. It consists of two cast-iron barrels suitably grooved to suit the tipping rope. One end of the rope is fixed to a barrel keyed to its shaft, and driven by a suitable reduction of gearing from the hoisting gear. This barrel is used to coil up the slack of the tipping rope when hoisting, and is provided with a suitable brake to hold the tipping block in position when using the crane for ordinary loads. A clutch is fitted, so that the barrel may be disconnected from the hoisting gear when desired. The other end of the tipping rope is coiled round a barrel mounted on the same shaft, but bushed with gun-metal and arranged to revolve free of the shaft. This barrel is driven by a 180-brake horse-power motor, through the medium of two reductions. Two parts of the tipping rope pass over two sheaves at the head of the jib, and the bight of the rope passes round a sleeve to which tipping chains are attached. An automatic electric brake, similar in construction to that on the hoisting motor, is fitted to the tipping motor.

The electrical equipment is suitable for a continuous-current circuit of 440 volts, and each motion is fitted with a separate motor. The hoisting and tipping and travelling and slewing motors are duplicates of each other respectively. The motor generator consists of two open-type machines coupled together, and mounted on one bedplate. The motor is shunt-wound, and the machine is normally one-hour rated, with a temperature rise of 70 deg. F., but if the shunt is continually on the temperature rise of this part is increased to about 80 deg. or 85 deg. F.

The slewing motor is of the semi-enclosed series-wound reversing type, capable of developing 50 brake horse-power for one hour with a temperature rise of 70 deg. F. when running at a speed of about 400 revolutions per minute. The travelling motor is of the totally-enclosed series-wound reversing type, rain-proof, and as far as possible dust-proof, and capable of developing 50 brake horse-power for one hour, with a temperature rise of not exceeding 90 deg. F. when running at a speed of about 400 r.p.m. The size of the motors permits of an overload of 25 per cent. for one half-hour and 50 per cent. for five minutes, and the whole of the equipment is capable of withstanding an alternating-current test of 2,000 volts for one minute.

The whole of the machinery is fitted in a house on the base of the machine, and there is a small hand-operated overhead electric crane for use when disassembling any part of the gear for examination and repair. The driver's cabin is situated in an elevated position, and is a steel-framed house with windows which give complete command of the surroundings. The whole of the controller's switch gear and levers for operating the various motions of the crane are arranged in this cabin. The crane is lighted with 40 incandescent lamps, each of 50 c.p., with a portable lamp in the operator's and machinery cabins.

## THE FAILURE OF BOILER PLATES IN SERVICE.

*The Failure of Boiler Plates in Service, and Investigation of the Stresses that Occur in Riveted Joints.**

By E. B. WOLFF, Dr.Ir. (Bussum, Holland).

THIS research was undertaken with the view of finding the causes of the cracking of boiler plates over the riveted seams.

The boilers were of the single-ended ordinary marine type, with three flues. The shell plates and the rivets were generally approximately 32 millimetres thick, made some from basic and some from acid open-hearth soft steel with an ultimate tensile strength of 42–48 kg./mm² and an elongation of 23 per cent. to 20 per cent. on 10 diameters. The phosphorus and sulphur contents had to be under 0.05 per cent. After the plates had failed these particulars were checked, and the plates, as far as the above-mentioned rules prescribed, were found to be good. Most of the boilers with the cracked plates belonged to steamship companies, the boats of which made voyages with a great many stops, so that the fires were frequently extinguished and relighted. Most of the boilers being oil-fired, this could be done very easily. The plates of coal-fired boilers, however, cracked in the same manner. Boilers made of the same material for other companies, the boats of which had only long non-stop runs, did not fail.

The dimensions of some of the boilers and of the joints are shown in Fig. 1, page 327.

The researches were started after one of the boilers had exploded. An investigation of this case showed that the explosion had been caused by the shell plate of the boiler having burst open in the middle of the double butt strap joint at the side. Through the large opening the contents of the boiler had been ejected, destroying the hull of the ship and causing much damage. The ship was fortunately lying alongside a quay, so that it was not lost. Had the explosion occurred an hour later, probably nothing more would have been heard of the ship.

After the rupture the shell plate, at the place where it had failed, had a thickness varying from 33 mm., the original dimension, in the middle, to 27.5 mm. and 28 mm. at the sides (Fig. 2, page 327).

As the plates had an equal thickness in all other parts, the only possible explanation of this difference was that the plate had failed by the forming of a crack in the middle of the length of the boiler, this crack having gradually developed to such an extent that the sound part at the sides could not withstand the boiler-pressure and failed suddenly, showing a reduction of area only in that sound part. As at the time the direct cause of this disaster could not be ascertained, it was decided to take out of service all boilers made of the same material and at the same time as the burst boiler. One of these was sent on, taken to pieces, and examined thoroughly. It was found that a large part of the shell plate, under the butt strap cover plate, had cracked. The crack could only be detected by taking off the cover plate (see Fig. 3, page 327). From the figure it can be seen that if the boiler had been kept in service much longer a similar disaster would have followed.

In the years following other boilers, made with every precaution and good workmanship, and of the best material obtainable, also cracked, but not always in the same seam; sometimes the lap joint, joining shell plate and front plate, failed; in other cases both joints developed cracks in some parts. It would take too much space to give a full description of all the tests made to obtain an insight into the mechanism of this cracking. It will be sufficient to give a general review of the results. The author here wishes to observe that he has found the same kind of cracks in cases of leakage of ordinary Lancashire factory boilers, and in a case of the cracking of the water-drum of a Yarrow-type marine boiler.

The investigations included tensile and bending tests, macroscopical and microscopical examination and chemical analyses of the material. The continual observation of the boilers in service at sea being much more severe in later years, several cases were detected where cracks had only just started.

*General Description of the Cracks.*—All the cracks

* Paper read before the Iron and Steel Institute on Friday, September 21, 1917.

found are, in the beginning, defects of microscopical dimensions. After having increased in length and breadth they could be detected. It would occur that a boiler, the side seam of which had failed, would be sent back to the boiler-shop to be fitted with a new shell plate. After detaching the front plates, nothing abnormal would be seen, and it would be decided to make use of the old front plates and fit new shell plates to them. The shell plates were bent with great care to the radius of the front plates and bored in position. When the first rivet joining the front and shell plates was put in, cracks appeared in some of the old rivet-holes of the front plate. By a renewed examination of the other rivet-holes, after cleaning the metal by scraping it carefully and later etching it, minute cracks were detected. The etching of the front plate, in the manner presently to be described, disclosed a great many miniature cracks, so that it was impossible to use it any more.

As has been stated above, the cracks were found in the butt joints as well as in the lap joints, but in all cases they started either from the inside of the holes, in two places, where the highest tensile stress occurred, or at the surfaces of the plates, where they were pressed on the surfaces of other plates. The fact that cracks start frequently on the inner surfaces of boiler plates has been mentioned by several investigators,* but a good indication of the causes has not been given. The accompanying illustrations (Figs. 5 and 6), give a clear view of the peculiar form of these cracks.

It will be seen that the cracks cover a certain part of the surface, depending on the direction of the stresses that acted on that part. Where they are found in the rivet-holes of the plates, they occur generally on two sides of the holes; in the case of the pipe-holes of the tubular boiler they spread from the top of the hole inward. When they occur on the surface of the plate, it is in general mostly around the rivet-holes, but also in other places. Figs. 4, 7 and 8, and engravings Figs. 5 and 6 above and Fig. 9 (Plate XXX), give a clear view of the way in which these cracks occur.

As mentioned above, the cracks start as miniature surface cracks of microscopical dimensions; it appears that every little crack has been formed by itself, without the slightest reference to its neighbours. A polished and etched section through these cracks shows that the crystallites in the immediate neighbourhood have not been deformed (Fig. 10, Plate XXX). The structure of the material has in most of the cases been found quite normal, no free cementite being present. Afterwards the cracks grow in length and depth, and unite in longer ones, forming a peculiar stepped line.

All evidence points to a peculiar form of destruction of the surface layers of otherwise very plastic metal. As the cracks always started at the surface of the metal and in the holes over the entire thickness of the plate, phosphorus or sulphur segregations, if these had occurred, could have had no influence. No segregations of importance were, however, found in most of the cracked plates. At first it was thought that the deformation of the material in the rivet-holes made by the boring of these holes might have had a great influence. As it was not possible to produce similar cracks in holes that were bored with a blunt drill, and as pieces cut out of such a hole and bent open, till the deformed surface broke,

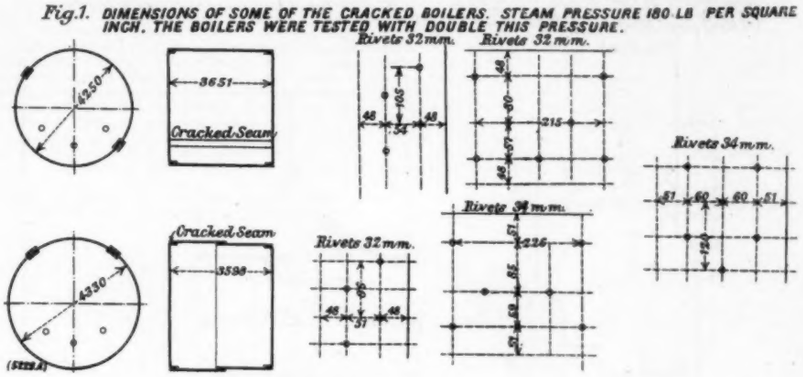



Fig. 1. DIMENSIONS OF SOME OF THE CRACKED BOILERS. STEAM PRESSURE 180 LB PER SQUARE INCH. THE BOILERS WERE TESTED WITH DOUBLE THIS PRESSURE.

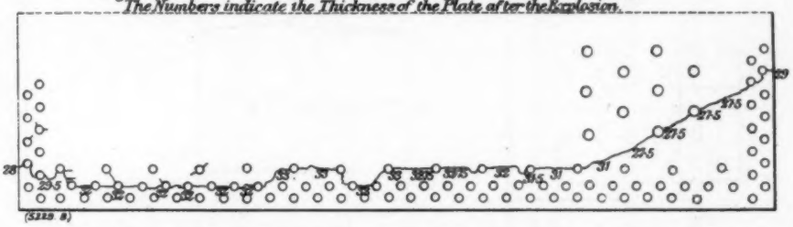



Fig. 2. JOINT OF EXPLODED BOILER SHOWING LINE OF FAILURE. The Numbers indicate the Thickness of the Plate after the Explosion.

FIG. 3.—Cracked boiler. Coverplate removed.

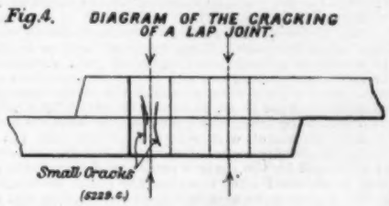



Fig. 4. DIAGRAM OF THE CRACKING OF A LAP JOINT.

FIG. 5.—Cracks in a rivet hole of a butt strap joint after etching. Vertical dimension is the thickness of the plate, 32 mm.

FIG. 6.—Cracks on the surface of a shell plate after etching. (Butt strap joint.)

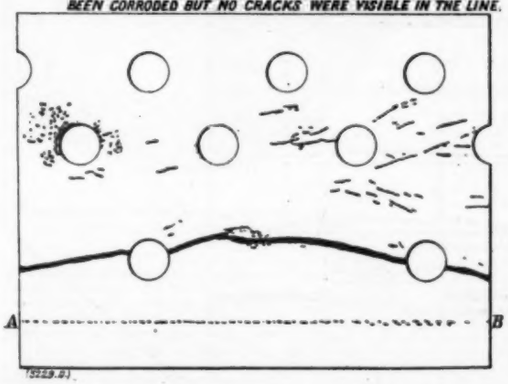



Fig. 7. DIAGRAM OF THE CRACKS IN THE PLATE SHOWN IN FIG. 6. A B IS THE DEFORMATION CAUSED BY THE CAULKING OF THE JOINT. THIS DEFORMED PLACE HAS BEEN CORRODED BUT NO CRACKS WERE VISIBLE IN THE LINE.

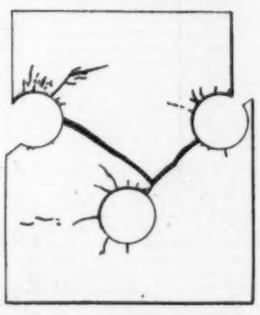


Fig. 8. DIAGRAM OF CRACKS IN A SHELL PLATE (LAP-JOINT, JOINING SHELL PLATE AND FRONT PLATE). THIS JOINT HAD BEEN RIVETED BY HAND.

* C. Sulzer, "Wärmespannungen und Ritzbildungen," *Zeitschrift des Vereins deutscher Ingenieure*, 1907. Report by the National Physical Laboratory of an investigation of some unusual defects in the plates of two combustion chambers on board a foreign-going passenger steamship, and note by the engineer-surveyor-in-chief: "The cracks themselves were unusual, as they appear to have started at the inner surfaces, where the plates were laid together for riveting, and were invisible until extended through the plates."—*Engineer*, 1910.

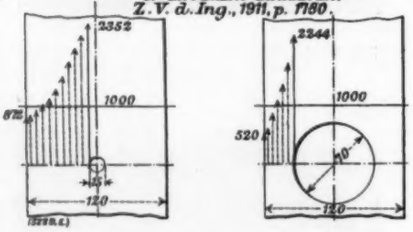
showed sufficient deformation before breaking, it was concluded that if the deformation had been one of the causes, it could only have been a secondary one. As hand-riveted joints cracked in exactly the same manner as joints where the rivets had been pressed in by the hydraulic riveting machine, the pressure of this machine on the plate also cannot be the cause of the cracking (Fig. 8, page 327).

Parts of the cracked plates, where no cracks occurred, were tested by joining them by rivets, driven in with the maximum pressure the press could give. Afterwards the rivets were taken out and the plates examined and bent. Here a great deformation of the surface also preceded the rupture (Figs. 11A and 11B, Plate XXX).

To reveal the miniature cracks it was found necessary to etch the metal with dilute sulphuric acid (1 : 10) during 24 hours or more. Before this etching the cracks were covered by the surface oxides, and they could not even be detected after scraping the plates thoroughly. It was necessary to ascertain that this etching did not cause similar cracks. It was found that in no case of deformation could cracks be seen after etching, not even if the metal were left in the etching solution for an abnormally long time. The deformed places were corroded in most of the tests before the rest of the metal, but this corrosion never caused sharply defined cracks. By an abnormally long immersion the deformed places could not be differentiated from the neighbouring metal; the cracks, however, showed very clearly. Microscopical sections through non-etched parts showed that the cracks were clearly to be seen without the aid of an etching solution.

Some parts of plates from other seams of the cracked boilers did not even show cracks after prolonged etching.

Fig.15. DIAGRAM OF THE STRESSES MEASURED BY PREUSS IN TENSILE TEST-BARS WITH HOLES OF DIFFERENT DIAMETER.
Z. V. d. Ing., 1911, p. 1180.




again. It dissolves the metal quite regularly, and discloses even the finest cracks. The only phenomenon known where cracks of the kind described have been observed in plastic material is that known as "fatigue." The beautiful researches of Ewing and Humfrey have

DIMENSIONS OF TEST-PIECES. THE SIDES OF THE PIECES WERE PLANED TO THE TANGENT TO THE RIVET-HEADS AFTER THE RIVETING HAD BEEN FINISHED

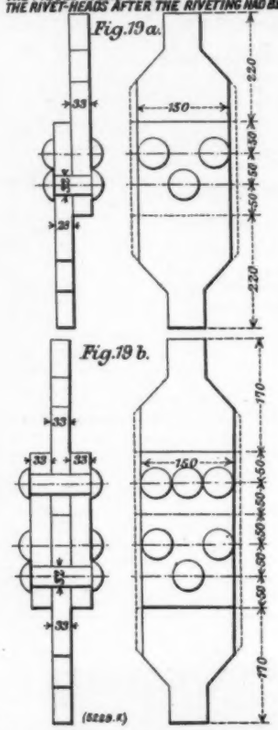
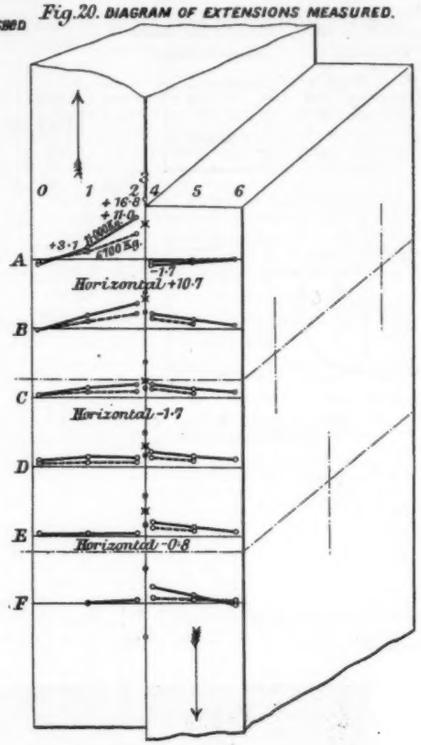



Fig.20. DIAGRAM OF EXTENSIONS MEASURED.




DIAGRAMS OF EXTENSIONS MEASURED.

Fig.21.

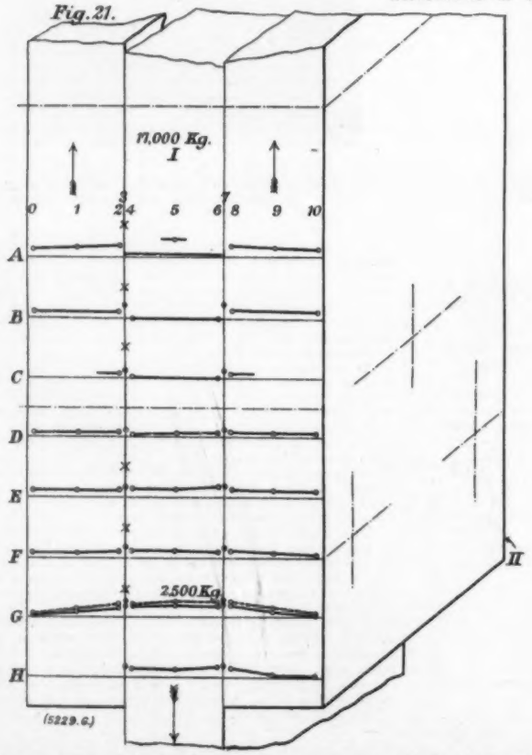
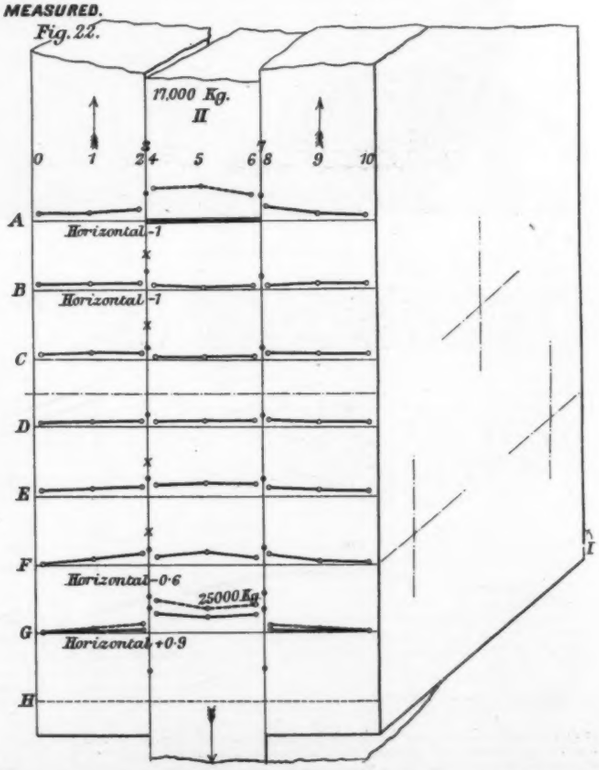



Fig.22.




Test-pieces were made by joining two pieces of the cracked plates, provided with new holes, by new rivets. These rivets were taken out afterwards, and the plates were etched, but no cracks appeared (Fig. 12, Plate XXX).

The etching with sulphuric acid has been of great aid in detecting the bad plates from those that could be used

disclosed the mechanism of the formation of these very local hair-cracks in plastic metal. A case of the formation of similar cracks in a large shaft, where overloading in service could be proved, showed quite the same kind of cracks after etching with diluted sulphuric acid (Fig. 13, Plate XXX).

From [photomicrograph (Fig. 14, Plate XXX) it will be seen that the crystallites in the immediate neighbourhood of the crack were not deformed. This was also the case with the boiler-plate cracks. These parts in the boilers being subjected to stresses of such magnitude, it may be asked how it is that the few alternations

during the lifetime of a boiler can cause these cracks. It may be observed, in the first place, that the ships with boilers that have cracked made relatively short voyages along the coast, and that in the beginning no care was taken to avoid changes in the steam pressure. When, later, care was taken to maintain the steam at a regular pressure, the cracking diminished, but did not

stop altogether. The first boilers were oil-fired, and were made of basic open-hearth material; afterwards boilers, both oil- and coal-fired, made of first-quality Scottish acid steel cracked in the same manner. Notwithstanding the severe conditions of the service, the number of the alternations is, however, only few when compared with that required to produce ordinary fatigue breaks. Only when it can be proved that at the places where the cracks are found abnormally high stresses can occur, may we accept "fatigue" as the cause of these cracks. It was necessary, therefore, to start an investigation of the stresses occurring in these parts of a boiler.

It is known from the theory of Kirsch and Leon, and the tests by Preuss, that the tensile tension at the edges of a hole in a bar loaded in the direction of its axis may amount to three times the average tension calculated for that bar (Fig. 15, page 328, and Fig. 16, Plate XXXI). When it can be proved that the holes of a riveted joint can behave as in ordinary bars, we have an explanation for the fact that the tensions at the edges of the holes can reach a very high value. The average tensional stress in the cracked plates was approximately 11 kg./mm. When this value is trebled we reach such a high stress in these places that very few alternations will suffice to cause a crack. It is thus necessary to prove that the friction between the plates will not be sufficient to counteract the deformation of the sides of the holes.

With a view of testing this, and in order to learn the values of the local stretch in different places of the surfaces of the plates that are pressed against each other, the author has made use of a special type of extensometer, designed by Mr. Okhuizen.

It consists of two knife-edges that are pressed to the surface where it is sought to ascertain the elongation as a measure of the stress. The change in the distance between these edges, one of which belongs to the fixed part, the other to a movable one, can be read from a scale by means of a simple arrangement of levers. Figs. 17 and 18 (Plate XXXI) give a good view of this apparatus and the mode of mounting it on the surface of the test-piece. The dimensions of this extensometer have been chosen so as to make one part of the scale equal to $\frac{1}{1575}$ mm. On iron or steel, with a modulus of elasticity of 2,150,000, one part of the scale corresponds to 1 kg./mm.². The test-pieces were riveted with great care in exactly the same manner as the riveting of a real boiler. The plates were of the thickest kind used in boiler design; the rivets were put in with the ordinary heavy pressure. The dimensions are shown in Fig. 19, page 328. The test-pieces were put into the tensile testing machine and loaded to the amount necessary to produce stresses approximately equal to the ordinary working stresses of the boiler.

The extensometer was read in every place with the loads zero, maximum, and zero again. In all the measurements no permanent deformation occurred, the extensometer showing exactly the same figure of the scale before and after the loading.

The results are plotted in Figs. 20 to 22, page 328, one for the lap joint, the other two for both sides of the double butt joint. At every horizontal line, A, B, C, &c., being the lines joining the centres between the knife-edges of the extensometer, three readings were taken on every one of the plates, numbered 0, 1, 2, &c. (Figs. 20 to 22). Furthermore, a reading was taken with one of the knife-edges of the instrument on one plate, the other on the other. The figures for the plates marked 3 and 7 found in this manner have not been plotted on the diagrams, but are assembled in Table I—A, B, C. By correlation of the figures found for 2, 4 and 6, 8, with the corresponding readings 3 and 7, it has been possible to calculate the absolute distance of the points 2 and 4, 6 and 8 on each line A, B, C, &c. (diagram 23A above), when the test-piece is loaded.

In the tables the values of the local elongations of the material, in a great many places, can be read. These figures have been checked by repeating the test several times at some weeks' interval. The figures have no absolute value as measures of the tensile stress actually occurring in boilers, as the material in a test-piece is not in the same position as in a boiler, and it is only possible to extend these measurements to two vertical sections through the joint; but it is possible to learn a great deal from them as to the relative differences that will occur between the stresses in different places.

*The Lap Joint.*—From the diagram (Fig. 20) it can be seen distinctly that the plates are bent as a result of the somewhat eccentric loading. As this occurs in the same manner in a boiler, and as it is taken into account in several previous tests,* it is only mentioned here as being so clearly shown by this method. The elongations have been put down for two values of the total load, viz., 6,600 kg. and 11,000 kg. The accuracy of the measurements follows from the similitude of the lines for these two loads. The load of 11,000 kg. corresponds with 97.5 kg./cm.² surface of the plates, or 4.55 kg./mm.² surface of the rivets. In one of the cracked boilers these figures were 89 kg./cm. and 8.7 kg./mm.² at the working pressure of the boiler. (The boilers were tested at twice the working pressure.)

It can be clearly seen that although the plates are pressed together by the rivets, the material of both plates shows a similar elongation only in the immediate neighbourhood of the rivets. In all other places the elongation is different, so that the surfaces move along each other. This movement, which is entirely elastic, has been recorded by putting the extensometer with the knife-edges on different plates (A, in Table I).

The tensile stresses reach a maximum value at the inner surfaces of the plates, *i.e.*, the places where the cracks are observed to start. As these maximum stresses are far higher than the mean stress calculated for the entire section of the plate, it will no longer be surprising that in such spots even few alternations of stress will cause local cracks in these places.

*Double Butt Joint.*—The tests were executed with a total load of 17,000 kg., and one series was repeated with 25,000 kg. Here, too, the similitude of the two lines is an indication that the observations are exact (17,000 kg. corresponds to 35.5 kg./cm.² surface of the plate, and 7.1 kg./mm.² surface of the rivets; these values were for one of the boilers, 57.5 kg./cm.² and 7.1 kg./mm.²). The values found here for the elongations are much more equal, but the displacements of the corresponding points of the two plates again show a great variety, as can be seen from the diagrams. Although the plates had become thinner at the places where the rivets press them together, the measurements show that the under-part of the shell plate in the diagram (II, in Fig. 22) has almost supported the total load, the cover plates showing very little stress. The cause could not be ascertained without destroying the test-piece, but without doubt the same situation can occur in a boiler. The parts between the outside rivets of the joints will have even more freedom to move along each other than the part-at lines A and B in the diagrams. The absolute movements of the plates in relation to each other will be great. In a case where the situation is as in the under part of II (Fig. 22) the shell plate is free to move at this end; the stresses at the inner surfaces of the rivet-holes can then

Fig. 23A. DISTANCE OF THE POINTS 2-4 WHEN THE TEST-PIECE IS LOADED

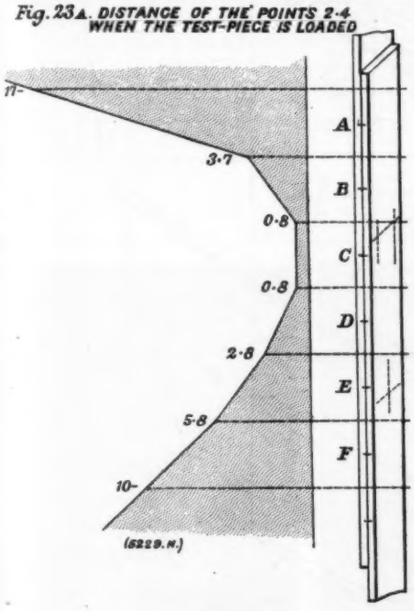
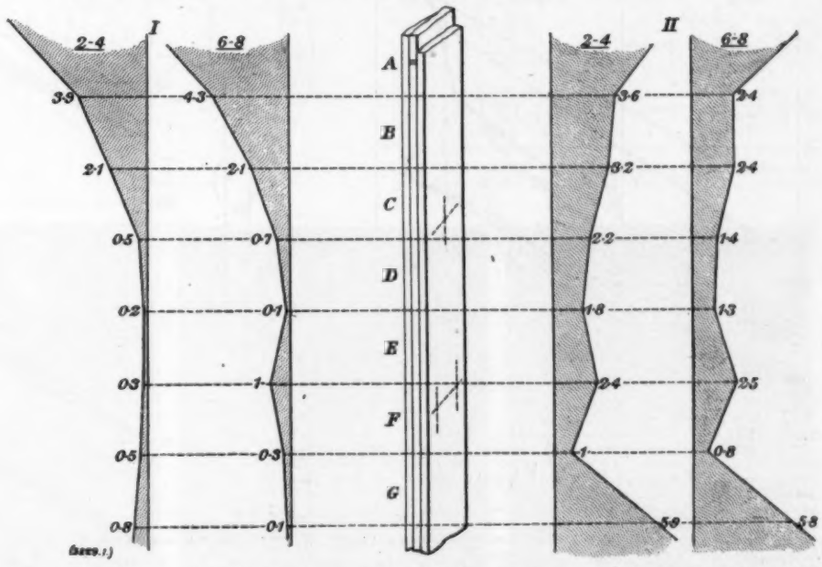



Fig. 23b. DISTANCE OF THE POINTS 2-4 AND 6-8 WHEN THE TEST-PIECES ARE LOADED.



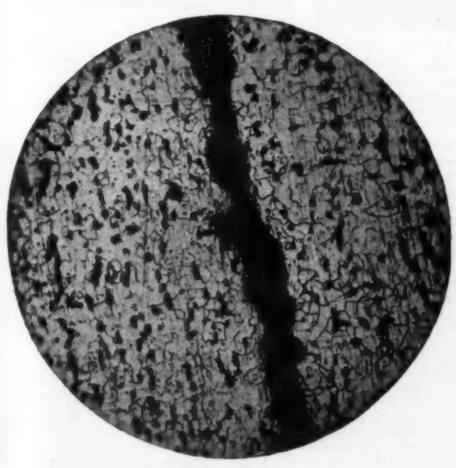



FIG. 24.—Separation line of shell plate and coverplate at F (fig. 21). × 50 dia.

*Table I.—Extensions Measured, 1 division = $\frac{1}{1575}$ mm.*

*A. Lap Joint.*

| | 0. | 1. | 2. | 3. | 4. | 5. | 6. |
|---|---|---|---|---|---|---|---|
| A | −1.4 | +3.1 | +11.6 | +16.8 | −1.7 | — | — |
| B | −0.6 | +3.6 | + 7.0 | + 8.0 | +4.1 | — | +0.6 |
| C | +0.8 | +2.7 | + 3.6 | + 4.6 | +3.6 | +2.2 | +1.7 |
| D | +1.2 | +2.4 | + 2.0 | + 5.0 | +4.0 | +2.8 | +2.1 |
| E | +0.1 | 0.3 | + 0.6 | + 6.4 | +3.6 | +2.0 | +0.5 |
| F | — | — | + 0.8 | — | +5.0 | +2.3 | −0.7 |

*B. Double Butt Strap Joint (I).*

| | 0. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 2.0 | —3.6 | —5.1 | — | — | —3.5 | —10.0 | | | | | |
| B | 1.7 | —1.9 | 4.0 | 0.1 | — | —4.3 | 2.2 | — | 1.3 | | | |
| C | — | —1.7 | 2.8 | 0.1 | — | —2.2 | 1.5 | — | — | | | |
| D | 1.5 | 1.5 | 1.6 | 1.9 | 0.9 | 1.1 | 1.1 | 2.1 | 1.7 | 1.7 | 1.6 | |
| E | 2.2 | 2.5 | 2.5 | 3.4 | 3.0 | 3.2 | 3.6 | 3.7 | 2.7 | 2.6 | 2.1 | |
| F | 1.2 | 1.8 | 2.4 | 3.0 | 2.6 | 2.7 | 2.1 | 3.2 | 2.8 | 1.7 | 0.6 | |
| G | 0.7 | 1.6 | 3.3 | 3.7 | 3.6 | 4.1 | 3.6 | 4.3 | 4.0 | 2.0 | 0.6 | |
| H | — | — | —3.3 | 2.7 | 2.5 | 3.4 | 3.6 | 2.8 | 0.5 | — | | |
| G | 0.9 | 2.7 | 4.6 | 5.0 | 3.9 | 5.5 | 5.0 | 5.4 | 5.2 | 3.1 | 1.4 | 25,000 kg. |

*C. Double Butt-Strap Joint (II).*

| | 0. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 1.9 | 2.0 | 3.0 | — | 9.1 | 9.7 | 7.5 | — | 4.0 | 1.9 | 1.4 |
| B | 1.5 | 1.7 | 1.7 | 4.9 | 1.3 | 0.1 | 1.1 | 3.5 | 1.1 | 1.6 | 1.4 |
| C | 1.4 | 1.5 | 1.6 | 3.5 | 0.6 | 0.5 | 0.7 | 3.0 | 1.7 | 1.5 | 1.2 |
| D | 1.3 | 1.5 | 1.8 | 3.6 | 1.4 | 2.0 | 1.9 | 3.5 | 2.0 | 1.5 | 1.3 |
| E | 1.7 | 2.3 | 2.7 | 4.8 | 3.3 | 3.9 | 3.8 | 5.1 | 2.6 | 1.9 | 1.1 |
| F | — | 1.5 | 3.5 | 4.1 | 2.1 | 3.7 | 2.1 | 4.8 | 3.3 | 1.0 | 0.1 |
| G | — | 0.6 | 1.0 | 7.3 | 5.9 | 4.7 | 5.8 | 7.0 | 0.8 | 0.5 | — |
| G | — | 1.3 | 2.5 | 11.0 | 9.5 | 7.2 | 8.6 | 11.2 | 1.9 | 0.9 | — |

* E. Daiber, "Die Biegungsspannungen in überlappten Kesselnietnähten," *Zeitschrift des Vereins deutscher Ingenieure*, 1913, p. 401.

# FAILURE OF BOILER PLATES IN SERVICE.

*Fig. 25. SLIP OF A RIVETED JOINT. SLIP COMMENCES AT A LOAD OF 14·2 KG./MM² SURFACE OF THE RIVETS OR 170 KG./CM² SURFACE OF THE PLATES.*

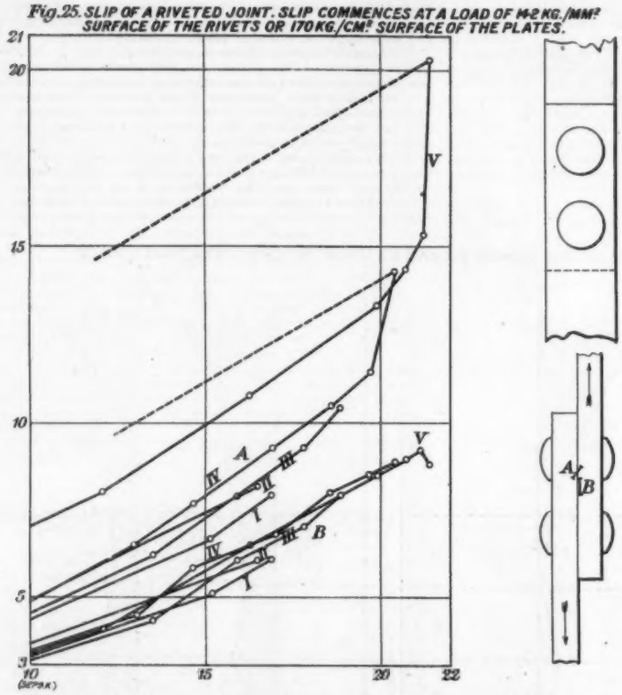
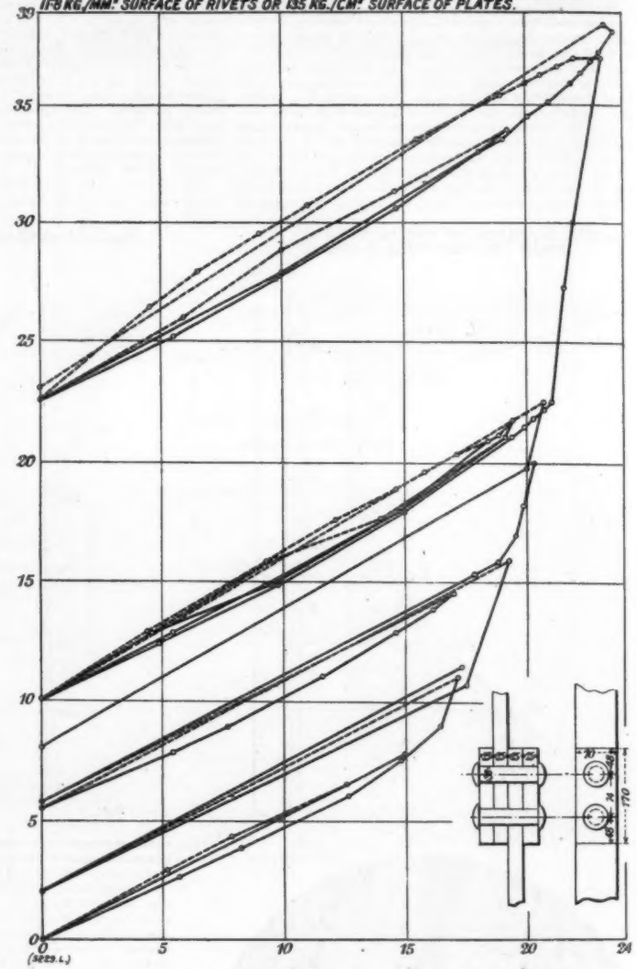



*Fig. 26. REPEATED SLIP OF RIVETED JOINT. SLIP COMMENCES AT A LOAD OF 11·8 KG./MM² SURFACE OF RIVETS OR 135 KG./CM² SURFACE OF PLATES.*




reach the higher values, according to the theory of Kirsch, &c. The other side of the test-piece (I, in Fig. 21), is in a far better condition. Here even the ends of the cover plates take part of the load, but here, too, the displacements at A and B are important.

It can be seen that the load is more or less gradually taken over from the shell plate by the cover plates; the gradual change will be different for every vertical section through the joint, depending on the position of the neighbouring rivets in relation to the section and on the pressure of these rivets on the plates.

Photomicrographs of the separation line of the two plates (Fig. 24, page 329) disclose the fact that in those cases where the plates have been cleaned before riveting by scraping them with a stiff brush, as in normal practice, the metallic parts do not come together, but are separated by a very compact layer of some sort of oxide. This layer has irregular breadth, the surface of the plate being very irregular under this magnification. When elastic displacements of the plates occur of the magnitude demonstrated, we can easily accept the supposition that stresses will hereby be caused high enough to explain the cracking of the plates.

*Slip of Riveted Joints.*—As different investigators have found that riveted joints begin to slip (permanent deformation) at relatively small loads, it was deemed interesting to confirm this fact with the Okhuizen extensometer and to learn how they will have changed after the deformation. From Fig. 25 it can be seen that, under the limit of elastic deformation, the lines for the series I, II, III, are fairly parallel, although at A the elongations for the same load are larger. In series IV, at a total load of 19,700 kg., the direction of the line A changed suddenly, the extensometer showing a permanent deformation after removing the load. On reloading it appeared that the line A had not changed its direction (V). This test was afterwards repeated with another test-piece (Fig. 26). The diagram will be clear enough to permit deductions to be made from it.

*Conclusions.*—It was proved that peculiar kinds of cracks occur in riveted joints of all kinds of boilers in service. These cracks are in most cases invisible in the beginning, and can then only be observed after etching the plates. They are found either on the inner surfaces of the rivet-holes or on the surfaces of the plates where these are pressed together. They are found in lap joints as well as in butt strap joints, in shell and front plates as well as in firebox plates. The real stresses in different places of the riveted joints have been measured by a special extensometer (Okhuizen) and it has been proved that the supposition that these cracks have been caused by "fatigue" of the material is probably right. The real stresses that occur in boilers can be even much higher than those in a test-piece. See, *e.g.*, Presidential Address by W. Cawthorne Unwin,* and Houghton,† "Failures of Heavy Steel Boiler-shell Plates," who states: "There is a considerable barrelling action, due to the ends of the shells being immovably fixed to the end plates, this being most severe in boilers in which only one strake of shell plating is fixed"; and Howard*. References to other literature are given below.†

ADDENDUM.

P. D. Merica‡ has published the results of an investigation on the embrittling action of sodium hydroxide on mild steel and its possible relation to seam failures of boiler plate. The conclusion drawn is that the influence of alkali on steel can be detected principally by means of the alternate bending test, the number of alternations being some 20 per cent. lower for the metal treated by the alkali than the values for the untreated metal. A recovery of the material occurs after a week's time of treatment at the temperature of 180 deg. C.

I should like to observe, in the first place, that the same kind of cracks mentioned in the present paper was found by Mr. Merica in different kinds of boilers; that the cracks described by me have occurred not only in the water-space, but also in the steam space of boilers; that the cracks being extremely local, in most cases no leakage was observed and no boiler scale was found between the plates; that as the boilers crack after having been in service for one or more years, recovery of the material from the effect of the alkali, mentioned by the author, should have taken place long before the cracks started.

* Proceedings of the Institution of Mechanical Engineers, 1915. ENGINEERING, vol. xcix, page 472.

† *Journal of the Iron and Steel Institute*, 1914, No. 1. ENGINEERING, vol. xcvii, page 647.

* International Testing Association; New York Congress, 1912.

† "Schroeder v. d. Kolk." Researches published by the Royal Dutch Society of Engineers, 1895. Bach, *Zeitschrift des Vereins deutscher Ingenieure*, 1892, pages 1142, 1305; 1894, page 1231; 1895, page 301. Frémont, *Revue de Métallurgie, Mémoires*, 1911, page 135. Talbot and Moore, Bulletin 49, University of Illinois, 1911.

‡ *Metallurgical and Chemical Engineering*, May, 1917.

§ Paper read before the Iron and Steel Institute, September 20, 1917.

## NOTES ON THE HEAT TREATMENT OF GREY CAST IRON.§

By J. E. HURST (Acton, London).

PART I.

IN a somewhat extended study of the properties of cast iron for internal-combustion engine cylinders, the question of the behaviour of this material, when subjected to the influence of heat, has been given considerable attention.

The rapid deterioration of cast iron cylinder components—the liner, piston, and valve chambers—is a subject of vital importance to the internal-combustion engine manufacturer. It is proposed in these notes to deal with the question of the behaviour of cast iron when subjected to heat, only in so far as it is concerned with the deterioration of the above-mentioned parts. Very frequently these cylinder components which are subjected to the direct influence of the heat crack and become utterly useless, in many cases after a short period of life only. This troublesome cracking is most pronounced in the cast-iron piston heads of Diesel engines.

The temperature which the centres of the above-mentioned piston heads sustain during working is undoubtedly very high. In the ordinary four-cycle gas engine, working at full load, it can be seen on looking along into the dark piston that the centre of the head is at a dull red glow, approximately 650 deg. to 700 deg. C. In the Diesel engine the flame resulting from the spontaneous ignition of the charge is driven directly against the centre of the piston head, and it is certain that the temperature of the inner surface in the centre of the piston head (directly in line with the fuel admission valve) is at least 900 deg. to 950 deg. C.

A typical sketch of the characteristic "star cracks" produced in Diesel engine piston heads after short periods of use is given in Fig. 1, page 331. In many instances these cracks can be traced to mechanical defects, such as bad design, defective cooling arrangements, &c., which tend under the influence of heat to set up unequal stresses in the material, a state of affairs which under the conditions of working—the high temperatures and high alternating gas pressures—in a Diesel engine is extremely liable to bring about fracture. It has been shown that the strength of grey cast iron* rapidly falls off with increasing temperatures, and it will be readily appreciated that the influence of unequal stresses due to mechanical or other defects under the conditions obtaining in the Diesel engine cylinder will be considerably more pronounced.

The analyses recorded in Table I, page 331, are taken as indicated in the table from various positions in cracked Diesel engine pistons. The only change indicated by these analyses is that of the condition of the carbon content—the combined carbon being practically wholly converted into free or graphitic carbon. From an

* Meyer, *Stahl und Eisen*, vol. xxvi.

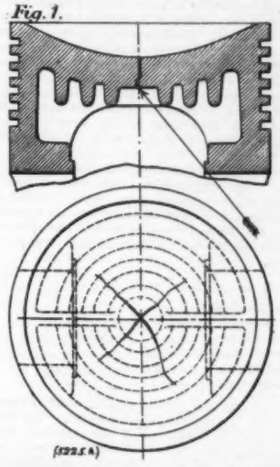
examination of the figures there would appear to be no indication of oxidation of the carbon or silicon contents as was experienced by Carpenter and Rugan in their well-known investigations on the growth of cast iron. In fact in piston No. 1 there is a decided excess of total carbon in the portions exposed to the action of the heat over that in the portions well removed from its influence. This state of affairs probably existed in the original casting.

TABLE I.

| Piston No. | Sample No. | Analyses. Combined Carbon. | Graphite. | Total Carbon. | Silicon. | Manganese | Sulphur. | Phosphorus. | Position. |
|---|---|---|---|---|---|---|---|---|---|
| | | p. c. | p. c. | p. c. | p. c. | p. c. | p. c. | p. c. | |
| (1) | 2 (*a*) | 0.15 | 3.49 | 3.64 | 1.60 | 0.63 | — | 0.134 | From inner portion of head exposed to heat (direct). |
| | 2 (*b*) | 0.55 | 3.14 | 3.69 | 1.86 | 0.45 | 0.064 | 0.162 | From outer portion of head away from heat. |
| | 2 (*c*) | 0.19 | 3.10 | 3.29 | 2.10 | 0.64 | — | 0.123 | From gudgeon pin boss far removed from heat. |
| (2) | 5 (*a*) | 0.05 | 3.22 | 3.27 | 1.91 | 0.68 | — | 0.122 | As above. 2 (*a*). |
| | 5 (*b*) | 0.19 | 3.03 | 3.22 | 2.05 | 0.74 | 0.055 | 0.121 | ,, 2 (*b*). |
| | 5 (*c*) | 0.19 | 3.13 | 3.32 | 1.93 | 0.68 | — | 0.120 | ,, 2 (*c*). |

valves. The turnings were covered with a large excess of cold dilute hydrochloric acid and allowed to stand for 48 hours. In no case was there any "micro-crystalline

*Fig. 1.*



(3225 A)

tube, and quenched in water at the room temperature. At a temperature of 750 deg. C. it will be seen that practically the whole of the combined carbon is rapidly converted into the free carbon form. All these samples were effectively quenched in water, and it will be noted that slow cooling is not a necessary factor in the dissociation of the pearlite in grey cast iron. Also it

TABLE II.

| Mark on Specimen. | Combined Carbon. | Graphite. | Total Carbon. | Silicon. | Manganese. | Sulphur. | Phosphorus. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | p. c. | p. c. | p. c. | p. c. | p. c. | p. c. | p. c. | |
| P1 | 0.50 | 3.35 | 3.85 | 1.87 | 0.834 | 0.005 | 0.016 | Original samples. |
| P2 | 0.50 | 3.51 | 4.01 | 1.79 | 0.742 | 0.005 | 0.106 | |
| P3 | 0.47 | 3.17 | 3.64 | 1.87 | 0.776 | 0.005 | 0.43 | |
| P4 | 0.44 | 3.08 | 3.52 | 1.89 | 0.44 | 0.05 | 0.85 | |
| P1. 1 | — | 3.72 | 3.85 | Not estimated | | | | 750 deg. C. for 2 hours. Quenched in water. |
| P2. 1 | — | 3.62 | 4.01 | | | | | |
| P3. 1 | — | 3.33 | 3.64 | | | | | |
| P4. 1 | — | 3.29 | 3.52 | | | | | |
| P1. 2 | — | 3.85 | 3.85 | Not estimated | | | | 750 deg. C. for 4 hours. Quenched in water. |
| P2. 2 | — | 3.96 | 4.01 | | | | | |
| P3. 2 | — | 3.61 | 3.64 | | | | | |
| P4. 2 | — | 3.53 | 3.52 | | | | | |
| P1. 3 | — | 3.73 | 3.85 | Not estimated | | | | 900 deg. C. for 2 hours. Quenched in water. |
| P2. 3 | — | 3.63 | 4.01 | | | | | |
| P3. 3 | — | 3.50 | 3.64 | | | | | |
| P4. 3 | — | 3.51 | 3.52 | | | | | |

FIG. 2.—Cracked Diesel Engine Piston, from gudgeon pin boss, showing normal structure of casting. Etched picric acid. × 50 dia. and reduced by one-third.

FIG. 3.—Cracked Diesel Engine Piston, from centre of head, showing structure after subjection to heat. Etched picric acid. × 50 dia. and reduced by one-third.

FIG. 4.—Cracked Diesel Engine Piston, from extreme edge of surface, affected by heat. Etched picric acid. × 50 dia. and reduced by one-third.

FIG. 5.—Cracked Diesel Engine Piston, showing portion of a small crack in affected portion. Etched picric acid. × 50 dia. and reduced by one-third.

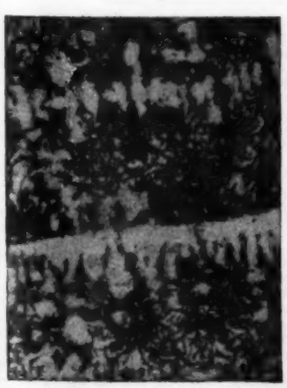


FIG. 6.—Sample P 1. Annealed 80 hours. Etched picric acid. × 250 dia. and reduced by one-third.

FIG. 7.—Grey Cast Iron (Normal). Etched picric acid. × 550 dia. and reduced by one-third.

FIG. 8.—Grey Cast Iron. Heat treated and quenched. Etched picric acid. × 50 dia. and reduced by one-third.

FIG. 9.—Grey Cast Iron. Heat treated and quenched. Etched picric acid. × 250 dia. and reduced by one-third.

It was attempted to determine "oxidised silicon" in each of these samples by the method briefly outlined by Rugan and Carpenter.* Samples of the turnings were powdered and placed in flasks fitted with Bunsen grey residue" obtained, and the final precipitate of silicon was quite white and flocculent.

A series of analyses given in Table II show the effect of heat treatment on the condition of the carbon content on a series of grey cast iron bars. The samples, the dimensions of which were 2 in. by 1¼ in. by ½ in., were heated for the stated periods of time in an open iron would appear that temperature between the limits of 750 deg. C. and 900 deg. C. has little influence on the rate of decomposition, nor does there appear to be any influence exerted by the varying phosphorus content.

Similar samples of grey cast iron were heated to a temperature between 900 deg. C. and 950 deg. C. for varying periods of time in an open iron tube. The

* Journal of the Iron and Steel Institute, 1909, No. II, page 95.

samples were each withdrawn after having been heated for the requisite length of time and quenched in water. The change in condition of the carbon content is illustrated by the analyses in Table III, from which it will be seen that a portion of the free carbon has been reabsorbed. It is very probable that the reabsorption of the free carbon has reached its maximum for the temperature of the experiment in sample 3, the high free carbon content in sample 4 being ascribed to ineffective quenching. There is a very noticeable increase in hardness in these specimens, sample 3 being perfectly glass hard.

This reabsorption of free carbon is most important, both from a practical and theoretical point of view. It will be noted that this experiment has been performed on a sample of high phosphorus cast-iron. Further experiments have been made on a complete set of varying phosphorus cast irons with a view to studying

Table III.

| Specimen. | Duration of Heating. | Combined Carbon Colour. | Graphite. | Total Carbon Combustion. | Silicon. | Manganese. | Sulphur. | Phosphorus. |
|---|---|---|---|---|---|---|---|---|
| Original metal | mins. — | 0.38 | p. c. 2.91 | p. c. 3.30 | p. c. 2.39 | p. c. 0.64 | p. c. — | p. c. 1.19 |
| (1) | 5 | — | 2.69 | — | — | — | — | — |
| (2) | 15 | — | 2.31 | — | — | — | — | — |
| (3) | 30 | — | 1.64 | 3.38 | — | — | — | 1.15 |
| (4) | 45 | — | 2.66 | — | — | — | — | 1.13 |

this phenomenon in greater detail. It is intended to make these the subject of Part II of this paper.

*Microstructures.*—Figs. 2, 3, 4, and 5, page 331, are the photographs taken from various portions of the cracked Diesel engine piston, as indicated.

Fig. 2 is taken from a portion of the piston well away from that affected by the heat. This shows the normal structure of a low phosphorus grey cast iron. The arrangement and distribution of the graphite plates and also the slight trace of dendritic structure will be noticed.

Fig. 3, taken from a portion of the piston which has been directly subjected to the influence of the heat, shows an enormous increase in the dendritic structure, and the whole of the matrix appears to be intersected by graphite plates. Near to the extreme upper edge of the piston, directly in contact with the flame, the extent of the dendritic structure is much less, and the matrix appears to be dotted with many more finely divided graphite plates, as shown in Fig. 4. The numerous small apparently holes in this photograph will also be noted.

Fig. 5 shows the edges of a small crack in the piston head. Here again the dendritic structure is well marked, but somewhat less in extent, and the colonies of free carbon appear to be somewhat more finely divided.

Fig. 6, page 331, shows a similar dendritic structure. This is a photograph of sample P1, heat treated for a period of 80 hours (eight hours a day for ten days) at a temperature of 850 deg. to 900 deg. C. The numerous curly plates of free carbon will again be noticed. It is important to note that in the centre of this bar, in the "as cast" condition, a dendritic structure was evidenced, as in Fig. 2, but somewhat more well marked.

It is interesting at this stage to trace the changes taking place in the pearlite constituent during heating up, previous to its dissociation. The normal pearlite structure of a grey cast-iron piston is shown in Fig. 6, taken at a magnification of 550 diameters. At a magnification of 50 diameters the pearlite laminæ would be unresolved, and the structure presented would be practically identical with that of Fig. 2. On heating to a temperature of 800 deg. C. and quenching in brine a structure is obtained as shown in Fig. 8, page 331, and at a larger magnification in Fig. 9. It will be seen that the pearlite has undergone a partial modification and has been rendered resolvable at the low magnification of 50 diameters. This modification is apparently the "globular" or "bead-like" pearlite of Benedicks and Howe.* It is important to note that on prolonging the heat treatment no further "balling up" of the pearlite laminæ appears to occur. The globular form appears gradually to vanish. This is contrary to the effect observed on the prolonged annealing of mild steel.

It is very probable that each individual bead or globule of cementite dissociates *in situ*, depositing tiny flakes of graphitic carbon, and no doubt whilst some of these tiny flakes of carbon appear to be drawn alongside the pre-existing plates of graphite, the internal pressure consequent upon the increase in volume of these newly formed free carbon plates tends to press these small flakes together, producing the numerous larger plates of free carbon as seen in Fig. 6.

The last of the pearlite to dissociate in this manner appears almost invariably to be that adjacent to the phosphide eutectic grains. This fact has been noted by previous observers;† but the reason for it is still somewhat obscure.

The microstructures presented by the heat-treated samples in Table III appeared to be austenitic. A most pronounced swelling of the graphite plates was also noted in these samples.

It is very probable that the swelling of the graphite plates, or more rather the replacement of these plates by holes, is in some manner connected with the re-absorption of the free carbon. The difference in structure of the extreme inner surface of the cracked piston, Fig. 4, is probably connected with this same phenomenon and denotes a much higher temperature in this outer region.

In all the heat-treated samples it will be noted that the worm-like graphite forms appear to have swollen and become somewhat thicker. Undoubtedly this circumstance exerts a large influence on the weakening of the cast iron after subjection to heat and its consequent fracture. It is legitimate to conclude that as a result of these internal changes, which take place only in a localised portion of the piston top, the iron is rendered considerably weaker, and the slight volume changes which undoubtedly accompany these changes will be responsible for a condition of internal strain. Under the conditions obtaining in the Diesel engine cylinder, as already indicated, such a state of affairs will rapidly lead to fracture.

*Influence of Phosphorus.*—It has been found, as a result of long experience, that the ultimate cracking of Diesel engine piston tops (apart from those cases of mechanical defective pistons) can as a general rule be traced to the phosphorus content of the cast iron.

A typical analysis of an actual cast iron piston is given below :—

| | No. 330 M. Per cent. |
|---|---|
| Combined carbon ... ... ... | 0.78 |
| Graphite ... ... ... ... | 2.60 |
| Total carbon ... ... ... ... | 3.53 |
| Silicon ... ... ... ... ... | 1.92 |
| Sulphur ... ... ... ... ... | 0.144 |
| Phosphorus ... ... ... ... | 1.08 |

Cast iron pistons of this type almost invariably crack after actual use in the Diesel engine. By the reduction of the phosphorus content of the cast iron to the lowest possible limits the life of the pistons was considerably prolonged and the troublesome cracking practically eliminated.

In concluding this portion of the paper the author would beg to tender his most sincere thanks to Messrs. Richard Hornsby and Sons, to Messrs. Mirlees, Bickerton, and Day, and to other friends for their kind assistance at all times during his investigations.

* Benedicks, *The Iron and Steel Times*, May, 1909.

† W. H. Hatfield, Journal of the Iron and Steel Institute, 1915, No. II, page 122.

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Engineering Employers' Federation.—An advertisement in this issue suggests an important development in the Engineering Employers' Federation, as they desire to appoint, as technical assistants, two engineers with workshop and management experience. We presume that the intention is to assist employers, through the intermediary of two such experienced officers, in determining in regard to questions the consideration of which involves special technical knowledge.

Coal Gas for Motor Traction.—A committee of the Manchester, Liverpool and Counties Motor Users' Association have arranged that a paper be given to their members and interested non-members on the subject of "Coal Gas for Motor Traction," illustrated by lantern slides, and delivered by the well-known expert, Mr. W. M. Barrett, of the Manchester Corporation Gas Department. The meeting will take place on Friday, October 12, at 7 o'clock p.m., at the Midland Hotel, Manchester; a discussion is to follow. Any non-members of the association who would like to be present may receive invitation on writing to the secretary of the association, Mr. Ellis Green, Cromwell Buildings, Blackfriars-street, Manchester.

Industry and Education.—A meeting will be held in the theatre of the Institution of Civil Engineers, by kind permission of the council, on October 25, at 3.30 p.m., for the purpose of considering the establishment of a central organisation for improvement in and better co-ordination of engineering training and the appointment of a representative committee of engineering and educational interests to initiate action. Sir Maurice Fitzmaurice, C.M.G., president of the Institution of Civil Engineers, will preside, and representative engineers and educationists from all branches of these professions have signified their intention to be present. Those interested are requested to obtain invitations from Mr. A. P. M. Fleming, British Westinghouse Company, Trafford Park, Manchester, or Mr. A. E. Berriman, chief engineer, Daimler Company, Coventry, who are acting as honorary organisers for the committee responsible for arranging this meeting. Although engineering training has made great strides in the last twenty years, largely owing to the growth of provincial universities and technical schools, and to the good influence of some of the more important engineering institutions, it is a fact that the link between the industry and education is not forged as closely as it should be in the interests of the State, and a strong nucleus of opinion has grown in favour of forming a central organisation with co-ordination activities as the best means to secure the improvement that is desired. Engineering is one of England's most important staple industries, and it is of the greatest national consequence that all who are engaged therein from bottom to top should be representative of their highest respective types, and this can only be secured when the proper purpose and value of education is not only recognised but achieved in the widest sense of the term. In their respective spheres, the engineering institutions, the universities, and the technical schools have exerted a most valuable influence, and the time is now ripe for providing some central organisation through which their activities may be co-ordinated in such a manner as to give them a much wider effect. In fine, it should now be possible to forge a permanent link between the professions and industry of engineering, the universities and schools, and parents and boys who have chosen this fine career for their life's work.

## NOTES FROM THE NORTH.

Glasgow, Wednesday.

*Scotch Steel Trade.*—Despite the many difficulties with which steel makers have to contend at the moment, it is satisfactory to be in a position to state that, as week follows week, the record of output continues to increase in a most gratifying manner. Much of this is, of course, due to the recent improvements and extensions carried through in a number of the more important establishments, but even yet it has not been found possible to make any great headway with the arrears which have accumulated. The King's visit last week to Clydeside and to the vast steel and iron works of Lanarkshire has focussed considerable attention upon what cannot be described as other than the huge arsenal which now exists in the West of Scotland, and from which there is being poured out daily a tonnage of material required for war purposes much in excess, perhaps, of that in any other similar area in the kingdom. So far as is compatible with the available resources and the many restrictions, there is no doubt that the royal visit and the keen interest taken by His Majesty in every process shown and explained to him should do much to stimulate a further increase of output. Many inquiries were made regarding the labour troubles which are so constant a source of anxiety, and on every occasion the King was assured that satisfactory results might be expected. In many cases just now there is extreme difficulty in obtaining requisite supplies of raw and semi-finished material, a fact which often causes very serious and unavoidable delay. Export is quite out of the count at present, and the most stringent regulations are being observed on every side in order that the necessary tonnage may go where it is in most urgent demand.

*Malleable Iron Trade.*—In the malleable iron trade both the iron and steel branches are exceptionally busy, with Government orders absorbing practically the whole of the output. With these pressing and insistent demands there is the utmost difficulty in meeting the requirements of ordinary mercantile consumers, who, meantime, are very unfortunately circumstanced. Indeed, nothing is left for them at all, and the problem is how they are to carry on. For a time high-tensile steel was pressed into service for various purposes, being found quite a suitable substitute for iron, but, with a growing shortage, the price has very considerably increased.

*Scotch Pig-Iron Trade.*—Considering the active conditions ruling in both the steel and iron trades, the demand for pig-iron of all grades and the pressure for delivery, are not to be wondered at. Enormous supplies of hematite continue to be consumed at the steel works, while the iron works absorb as great a quantity of forge iron as is procurable, and the general engineering trade take a considerable amount of foundry quality. These heavy demands are, naturally, making the shortage more keenly felt, so that it is with increasing difficulty that licences are granted for shipments abroad. Throughout the tone is firm.

*Ironmoulders' Strike.*—No settlement has yet been arrived at in connection with the ironmoulders' strike, which has now been in operation since Friday week. The offer of 3*s.* per week advance, instead of the 15*s.* demanded by the men, is still being vigorously protested against, and even at a meeting held on Saturday, and attended by fully 3,000 men, no definite proposal could be arrived at. It is specially unfortunate that a strike of such magnitude should have taken place at a time when there is so urgent a demand for skilled workmen, and it is to be hoped that the whole question will speedily be adjusted.

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Calcium Carbide.—The Minister of Munitions has ordered as follows : (1) He has taken possession as from September 24, until further notice, of all calcium carbide, now or hereafter situated in the United Kingdom, except the stocks of persons who do not own more than ½ cwt. (2) If any person having control of any calcium carbide to which Clause 1 hereof applies, without the consent of the Minister of Munitions, sells, removes or secretes it, or deals with it in any way contrary to any conditions imposed in any permit that may have been granted in respect thereof, he will be guilty of an offence against the Defence of the Realm Regulations. (3) No person shall, as from the same date, until further notice, buy, sell or supply, except for the purpose of carrying out a contract in writing existing at the said date, or enter into any transaction or negotiation in relation to the sale or purchase of calcium carbide situated outside the United Kingdom, except under and in accordance with the terms of a permit issued under the authority of the Minister of Munitions. (4) No person shall, until further notice, offer to sell, sell, supply or deliver any calcium carbide situated in the United Kingdom except under and in accordance with the terms of a permit issued under the authority of the Minister of Munitions. (5) All persons shall, within seven days from the first day of each month, commencing in the month of October, 1917, send in to the Controller of Non-Ferrous Materials Supply monthly returns of : (*a*) All calcium carbide held by them on the last day of the preceding month ; (*b*) all calcium carbide purchased or sold by them for future delivery and not yet delivered on such last day ; (*c*) all calcium carbide delivered to them during the preceding month. No return is required from any person where the total stock of calcium carbide in hand and on order for future delivery to him has not at any time during the preceding month exceeded ½ cwt. All applications in reference to this order should be made to the Controller of Non-Ferrous Materials Supply, AM2/H, Hotel Victoria, Northumberland-avenue, London, W.C. 2, and marked "Calcium Carbide."

## NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

*South Yorkshire Coal Trade.*—The consumption of all classes of manufacturing fuel keeps on a large scale, and the full daily output of pits is required to fulfil contract orders. The open market has little or nothing of the best sorts on offer, and this class of trade is almost at a standstill. Collieries are being urgently pressed by consumers, especially the large works, to wipe all arrears off before the winter sets in, so that they may depend upon their small reserves, which have been accumulated under great difficulties, being conserved for actual winter operations and needs. The heavy home demands are not easily dealt with when considered alone, but when added to them there is a pressing inquiry for Government and allied Powers, the position does not lend itself to a ready solution. Gas companies are obtaining a good tonnage on contract account, but exporters have little of this class to offer. The house coal situation shows no signs of improvement, and dealers and agents are perplexed in thinking how to secure the full requirements for all the orders which have come to hand. Quotations:—Best branch handpicked, 20*s.* 6*d.* to 21*s.* 6*d.*; Barnsley best Silkstone, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire best brights, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire house coal, 17*s.* to 18*s.*; best large nuts, 16*s.* 6*d.* to 17*s.* 6*d.*; small nuts, 15*s.* 6*d.* to 16*s.* 6*d.*; Yorkshire hards, 16*s.* 6*d.* to 17*s.* 6*d.*; Derbyshire hards, 16*s.* to 17*s.*; best slacks, 12*s.* to 13*s.*; seconds, 10*s.* 6*d.* to 11*s.* 6*d.*; and smalls, 8*s.* to 9*s.* per ton at the pit.

*Iron and Steel.*—The greatest interest is still being displayed in the Sheffield industries by the authorities, and the output of steel is receiving particular attention. The more recent indents and specifications of the Government have been for larger quantities than before, and the firms have work on their books for many months ahead. Furnace improvements and additions are being made with rapidity, but the increase of electric furnaces has steadied down perceptibly owing to the reasons given the other day, that the Ministry of Munitions is now exercising a controlling influence in this direction. The local equipment of electric furnaces, however, is such as to gladden the heart of those who consider that Sheffield's future prosperity rests upon the manner in which the large steel corporations adapt themselves to the newer method. It is stated that there is a real danger of the trade in making the high-class alloyed steels being diverted elsewhere if sufficient electric current is not forthcoming, and this has stirred the local "city fathers" into activity in regard to the adoption of the electric power extensions. The increase in the making of alloyed steels has been phenomenal of late and is attributed to the great demand for aeroplane, motor car and other special categories. The branches comprised by the lighter sections, such as files, saws and high-speed and carbon tools, are as busy as ever, but the indents are more closely related to customers nearer home than Russia, which was such an enormous consumer of these goods in the early part of the war. Agricultural engineers report that, in consequence of the intervention of the Ministry of Munitions as buyers, through the agency of the Agricultural Machinery Department, they are now able to get the essential material with much less difficulty than up to a short time ago, and their output has been wonderfully improved thereby. The bar which prevents the manufacture of any more stainless cutlery is symptomatic of the general tightness prevailing in materials, alloys, &c., all over. The metal market has not undergone much alteration of late, but dealers still contrive to obtain the top tariff for all they can produce owing to the unprecedented demand. Overseas orders are good under the circumstances.

*Staveley Coal and Iron Company.*—Mr. Charles Markham, who is well known the mining world over, had some very pertinent remarks to make at the annual meeting of this company, which took place at Sheffield yesterday. He referred to the fact that in income-tax on dividend the company had paid the following sums during the past few years: In 1914, 7,710*l.*; 1915, 30,523*l.*; 1916, 47,558*l.*; and this year nearly 80,000*l.* At the beginning of the war they were paying about 900,000*l.* in wages per annum, but though they were now employing fewer men the wages had risen from 1,038,000*l.* in 1916 to 1,200,000*l.* to-day. The Controller's new scheme would mean that they would have to pay at the rate of 1*s.* 3*d.* to each collier, another 116,000*l.* per annum. On the top of that it had to be remembered that the miners were losing from 16 per cent. to 35 per cent. of their time. He did not think the shareholders were profiteering to the extent the working man was to-day, yet the masters were held up as aggressive tyrants, sweating the workmen. He thought the working men were to a great extent sweating the nation. A dividend of 15 per cent. was declared.

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SHIPPING BETWEEN MANILA AND THE UNITED STATES.—According to *The Electrical Review*, Chicago, the Pacific Mail Steamship Company is making Manila, Philippine Islands, the distributing point for United States products destined for various places in the Far East. Lack of transportation facilities between Manila and other points in the Philippine Islands is reported serious, and Manila business interests have asked that the smaller German boats seized be allowed to remain there for local use. For external trade, cargo space is reported available for imports from North America, but shipments from the Philippines eastwards are difficult to arrange, because of overcrowded ships and excessive rates. This indicates a tremendous demand for tonnage from the Far East across the Pacific. Similar conditions are experienced at Singapore and other points in the Straits Settlements.

## NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

*The Cleveland Iron Trade.*—Applications for home supplies of Cleveland pig-iron next month are very heavy, and the commencement of the issue of October allocations is on a very liberal scale, so that, with iron quite plentiful, next month's deliveries to North of England customers and consumers north of the Tweed promise to be large. Signs are not wanting of further expansion of foreign trade. All sales to France are still conducted through official channels, but recently merchants' sales to Italy have been rather considerable, and licences for their despatch are expected to be granted so that they can accompany substantial clearances of coke for which tonnage has been arranged. For home consumption No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge all stand at 92*s.* 6*d.*, and No. 1 is 96*s.* 6*d.*; and for shipment to the Allies No. 3 is 102*s.* 6*d.*, No. 4 foundry 101*s.* 6*d.*, No. 4 forge 100*s.* 6*d.*, and No. 1 107*s.* 6*d.* There is still no change to record in the stock of Cleveland pig-iron in the public warrant stores, the quantity held remaining at 1,137 tons, all of which is No. 3 quality. The last change was on July 7 last, when 221 tons were withdrawn.

*Hematite Iron.*—The East Coast hematite branch of trade presents few new features of moment. Conditions continue very stringent, but hope of relief is looked for at no very distant date by extended manufacture of basic iron from native ores, preparation for such production being pushed forward as energetically as circumstances permit. Very careful distribution, under the strict supervision of the Control Committee, still enables home consumers to receive adequate supplies, but when such needs have been met very little iron is left over for sale abroad. Export demand is extremely heavy, and altogether impossible to satisfy, but it is gratifying to have the assurance that rather more iron is being dispatched to our Allies in fulfilment of contracts made some time ago. A few home sales are recorded from time to time, but new export business is exceedingly difficult to put through. Nos. 1, 2 and 3 are 122*s.* 6*d.* for home use, and the recognised market rate for shipment to France and Italy is 141*s.*, but the export quotation is subject to the addition of excess foreign ore freights charged by neutrals above the parity.

*Coke.*—Very little new is ascertainable concerning coke. Export demand is rather better, and for shipment both beehive and patent oven stand at 42*s.* 6*d.* f.o.b., whilst gas-house product varies from 30*s.* to 31*s.* Local demand is heavy, and blast-furnace descriptions, though plentiful, still realise fixed maximum rates, average kinds commanding 28*s.* at the ovens, and low phosphorus qualities selling at 30*s.* 6*d.* at the ovens.

*Foreign Ore.*—The continuous demand for foreign ore is dealt with as quickly as tonnage becomes available. On the whole, deliveries are fairly well maintained, and are on a sufficient scale to keep consumers going.

*Manufactured Iron and Steel.*—New features in the finished iron and steel industries are few. Manufacturers are kept so fully employed on Government work and shipyard needs that they are not disposed to entertain ordinary commercial inquiries. Marked increases in deliveries of shipbuilding steel are reported. Prices all round are very stiff, but the only actual change this week is an advance in iron ship rivets. The following are among the principal market quotations:—Common iron bars, 13*l.* 15*s.*; best bars, 14*l.* 2*s.* 6*d.*; best best bars, 14*l.* 10*s.*; iron ship plates, 15*l.* 10*s.*; iron ship angles, 13*l.* 15*s.*; iron ship rivets, 19*l.*; packing iron and steel (parallel), 13*l.* 10*s.*; packing iron and steel (tapered), 15*l.* 15*s.*; steel bars (no test), 14*l.* 10*s.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel ship rivets, 20*l.* and upward; steel strip, 15*l.* 10*s.*; steel joists, 11*l.* 2*s.* 6*d.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.*

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FREIGHT CHARGES IN AMERICA.—The average freight rate earned by the American railroads in 1916 was 7.16 mills per ton-mile, which, with the dollar at its par value, is equivalent to about 0.358*d.* per ton-mile. At the same time the average operating expenses per train-mile rose from 1.77 dols. in 1915 to 1.83 dols. in 1916.

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VELOCITY OF CRYSTALLISATION OF METALS.—Since the velocity of crystallisation of metals cannot be determined in the same way as in the case of crystallisation from transparent solutions, J. Czochralski proposes a novel method in the *Zeitschrift für Physikalische Chemie*, vol. xcii, pages 219 to 221, April 24, 1917. With the aid of a small stand in which a pulley is fixed he lowers a rod of glass or quartz into the fused metal, which is contained in a crucible; the rod is suspended by a silk cord. An adjustable clockwork draws the rod up again; when the metal is crystallising a wire thread of the metal will adhere to the rod, and the rate at which the thread can continuously be drawn up without breaking is read off on a scale attached to the stand. In experiments with tin, lead, and zinc, which melt at 232 deg., 320 deg. and 416 deg. C. respectively, these maximum rates were 90 mm., 140 mm. and 100 mm. per minute. The thickness of the wire threads was less than 1 mm; by etching them with acids it was shown that the threads consisted of long-drawn-out crystals, up to 150 mm. in length. We are rather doubtful that this test really gives the rate of crystallisation; the purity of the metal and the rate of cooling may also be important factors. The test might be useful in metallurgical laboratories.

## NOTES FROM THE SOUTH-WEST.

*Cardiff.*—The publication of the list of classified coals under the new schedule of small coal prices has put the market in fuller information of the position in regard to small coal than it has been since the issue of the Coal Controller's directions last June. It is realised that it provides a wider basis of business, and in many cases has actually facilitated operations. The arrivals over the week-end and the early part of this week slightly improved the tonnage position, and except in a few cases all the pits in the steam coal area have been working. In the bituminous district the situation is less satisfactory, and it was reported this week that Swansea salesmen were offering through coal at figures considerably less than the minimum prices. The majority of the salesmen, however, are undoubtedly adhering to the scheduled figures, although the quantity of coal changing hands is extremely small. The difficulties of the inland reorganisation scheme are increasing instead of diminishing, and the Local Committee, at the request of the Coal Controller, has communicated with colliery companies, informing them in many cases that their allocations to the south-western districts have been cancelled, the explanation given being that coals more suitable for household purposes than those which could have been supplied from the collieries concerned are being obtained from other pits. It is stated that in at least some of the cases of the cancelled certificates the coal which was to have been sent to the south-western counties had become available by the prohibition of the transport of coals from the collieries concerned to south-eastern destinations. At present it is not clear whether the cancelling of the allocations to the south-western counties implies the return to the collieries of their right to send the cancelled steam and manufacturing coals to the south-eastern consumers.

*Newport.*—A slightly improved tone has been apparent in the market for Newport coals. This has been due, of course, to an improvement in the supply of tonnage, and its effect has been seen in a resumption of work at practically all the pits in the Western and Eastern Valleys. Smalls are still a glut on the market, but there has been a good demand for large, and inland business is fairly heavy.

*New Classification of Small Coal.*—The colliery companies have now received copies of the proposed classification of small coal under the new graded prices. The grades are now separated into eight classes, ranging at intervals of 6*d.* from 21*s.* to 18*s.* per ton. This new classification is regarded as a great improvement on the old, but it is pointed out that it still contains anomalies which are likely to react adversely on some of the collieries. It is, however, found exceedingly difficult to devise a scheme which could in any way approach perfection or give general satisfaction. A meeting of the Classification Committee was held on the Cardiff Exchange on Monday, when appeals which had been made by the collieries concerned for reclassification were to have been considered, but a special meeting for this purpose was convened for Friday of this week. It is understood, however, that the list will take effect almost entirely as now published.

*Contract Arrears Committee.*—The difficulty which has arisen between the coalowners and exporters over the chairmanship of the Cardiff and Swansea Joint Coal Contracts Arrears Committee has reached an acute stage. The issue, briefly put, is that at the preliminary meeting Mr. H. J. Hill, an exporter, was put in the chair. The exporters maintain that the selection of Mr. Hill was intended to be permanent, while the coalowners contend it was merely a temporary expediency, and the Coal Controller appointed Mr. Evan Williams and Mr. W. North Lewis, two coalowners, to be chairman and vice-chairman respectively. The exporters contended this was giving an undue advantage to the coalowners, and made representations to this effect to the Coal Controller; but the latter has now intimated that he cannot vary his decision. The result is that at a meeting of the exporters held on Monday it was decided to withdraw from the committee altogether. It may be added that a feeling prevails on 'Change that this is not an altogether regrettable incident, the belief being entertained that coalowners and exporters can deal with business more effectively by individual negotiations rather than through the medium of any committee.

*Colliery Examiners' Strike.*—In view of the notices given by the lower-grade officials who are members of the South Wales and Monmouthshire Colliery Examiners' Association to terminate contracts at the end of the month, deputations representing both the coalowners and the examiners waited upon the Coal Controller on Tuesday. On the suggestion of Sir Richard Redmayne, who represented the Controller, it was arranged that a joint committee, consisting of six representatives of the owners and a similar number of the examiners, be formed with the view of dealing with the points at issue, the examiners being asked to suspend the notices for a month pending the completion of negotiations. It was explained by the coalowners that 43 per cent. of the examiners in the coalfield had refrained from tendering notices.

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EXTENSION OF FRANCO-RUSSIAN INDUSTRIAL CONCERNS.—The South Russian Soda Manufactory, which is under State supervision on account of its work for the War Ministry, has decided to increase its Russian capital. A number of Russian chemical companies will be represented on the Board, and they have guaranteed the issue of 12,000 new shares of 167½ roubles at an exchange of 250 roubles.—The Usines Maltzof is about to increase its capital, which at present amounts to 32,000,000 roubles.

# 21-IN. HOLE CRANK-FORMING LATHE.

CONSTRUCTED BY MESSRS. THOMAS RYDER AND SON, LIMITED, ENGINEERS, BOLTON.

(*For Description, see Page* 340.)

*Fig.1.*

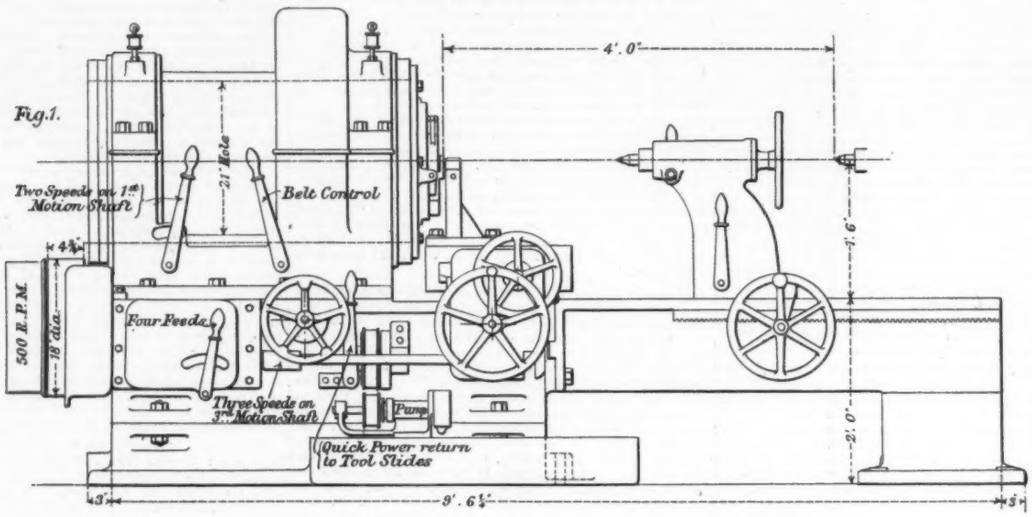



*Fig.2.*

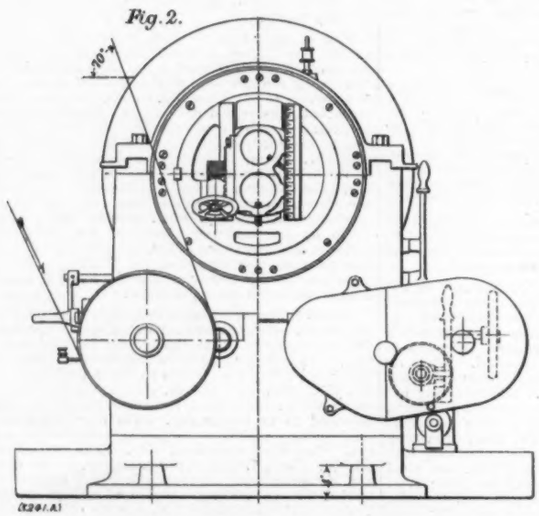
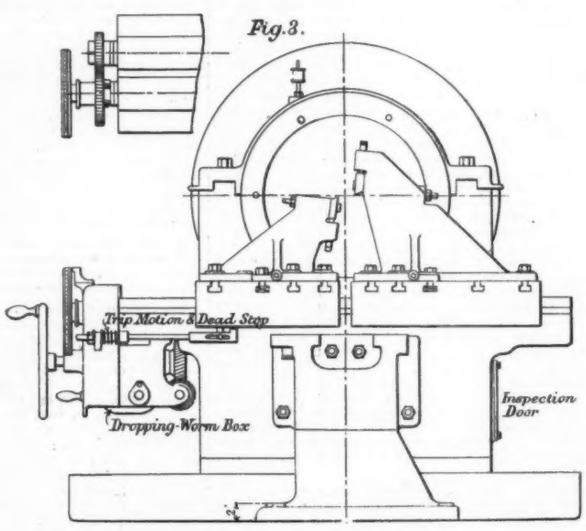



*Fig.3.*



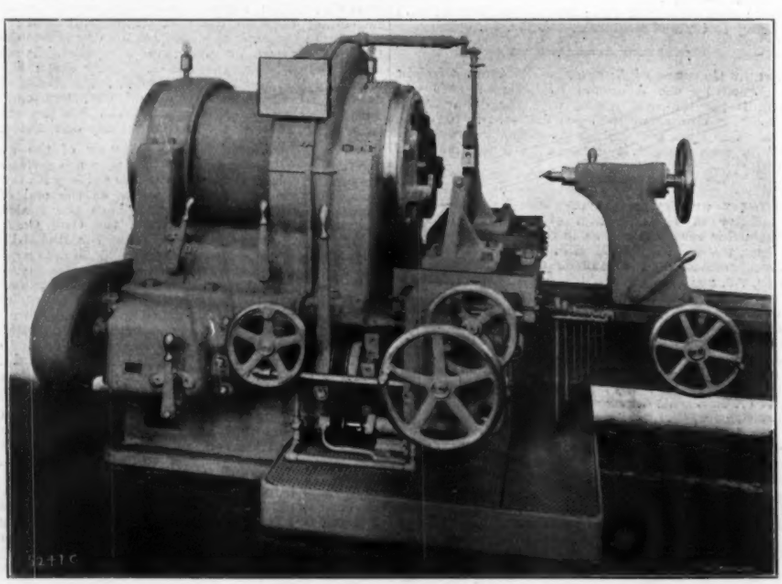



*Fig.5.*

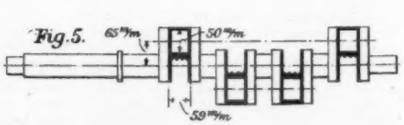



*Fig.6.*

*Fig.7.*

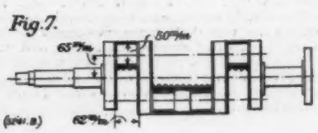



FIG. 4.

# 32-TON ELECTRIC TRAVELLING COALING CRANE AT GLASGOW HARBOUR.

CONSTRUCTED BY SIR WILLIAM ARROL AND CO., LIMITED, ENGINEERS, GLASGOW.

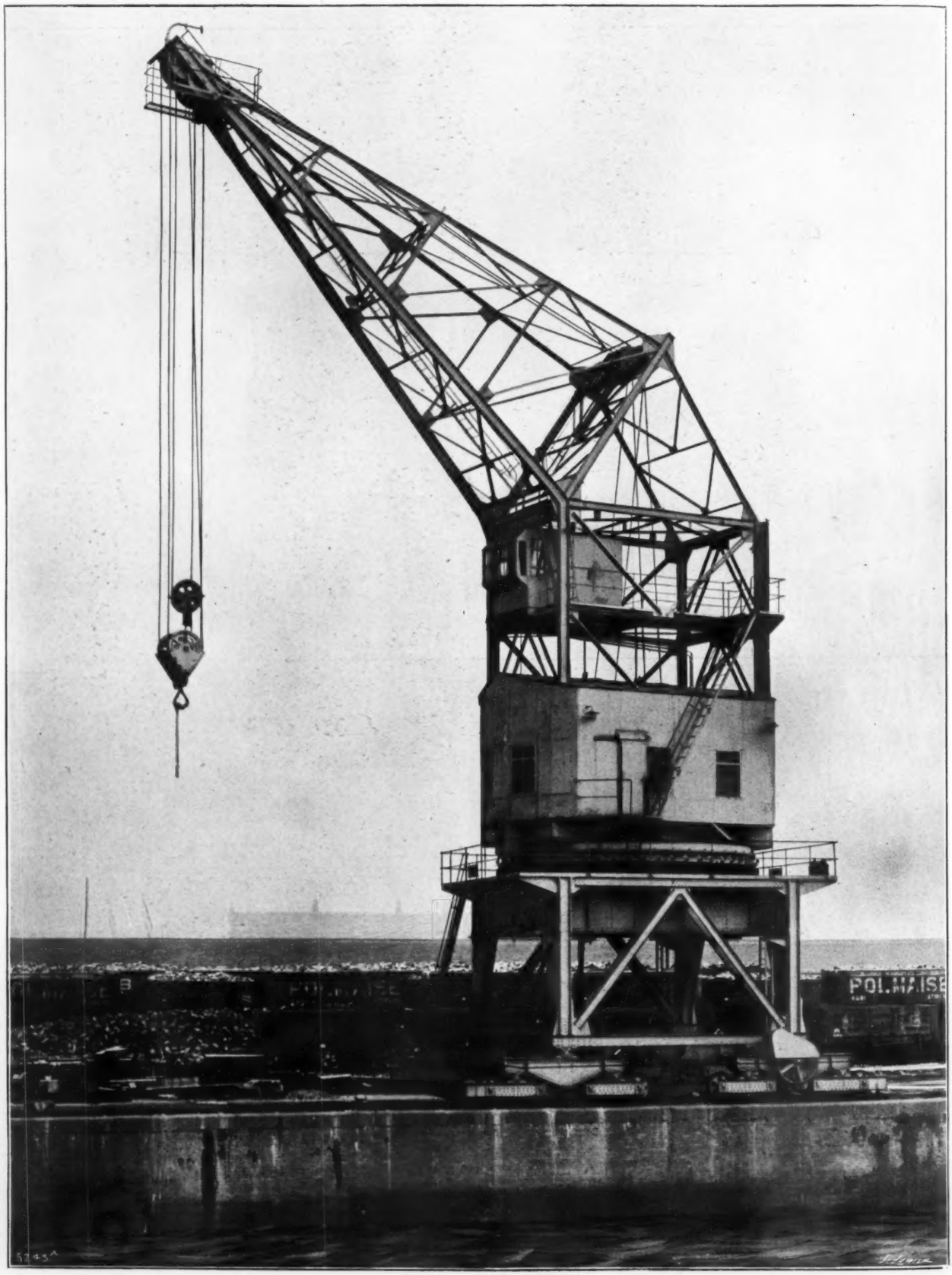
(*For Description, see Page* 326.)

(*To face page* 326).

# 32-TON ELECTRIC TRAVELLING COALING CRANE AT GLASGOW HARBOUR.

CONSTRUCTED BY SIR WILLIAM ARROL AND CO., LIMITED, ENGINEERS, GLASGOW.

(*For Description, see Page* 326.)



# THE FAILURE OF BOILER PLATES IN SERVICE, AND INVESTIGATIONS OF THE STRESSES THAT OCCUR IN RIVETED JOINTS.

(*For Description, see Page* 326.)

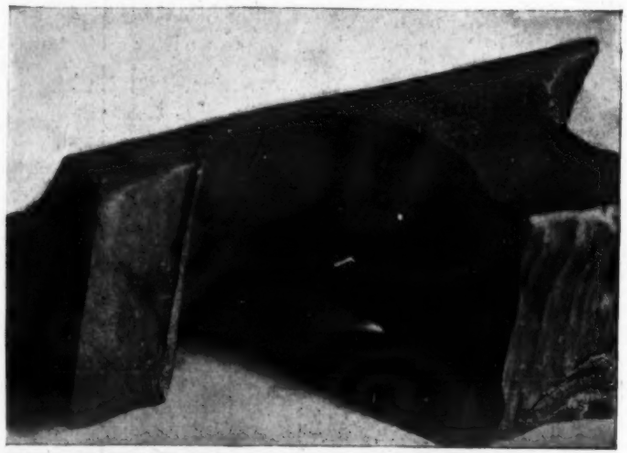
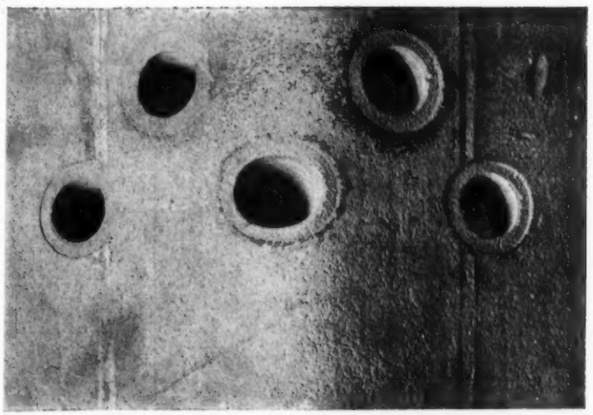
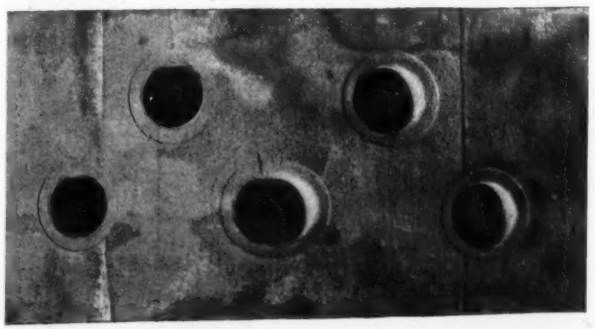


FIG. 9.—Cracks in the waterdrum of a tubular boiler of the Yarrow marine type. The distance of the holes for the pipes to the edge of the thicker part of the shell had been made too small; after some years of service cracks appeared at the outer surface. After taking the tubes out and etching the holes, miniature cracks did appear even in holes that had seemed faultless.

FIG. 10.—Cracks in a shell plate. × 50 dia.





FIGS. 11A and 11B.
Test pieces bent after joining by rivets and removing the rivets.

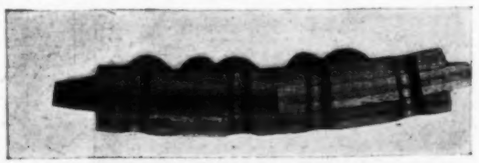


FIG. 12.—Etched test piece, where no cracks were detected.

FIG. 13.—Slice cut from a large shaft, cracked after serious overloading. The cracks have been made visible by etching.

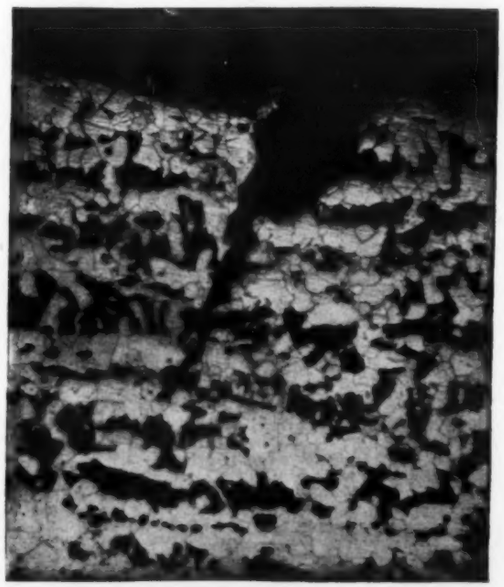


FIG. 14.—One of the cracks in the shaft. The crystallites have not been deformed. × 80 dia. and reduced.

# THE FAILURE OF BOILER PLATES IN SERVICE, AND INVESTIGATIONS OF THE STRESSES THAT OCCUR IN RIVETED JOINTS.

(*For Description, see Page* 326.)

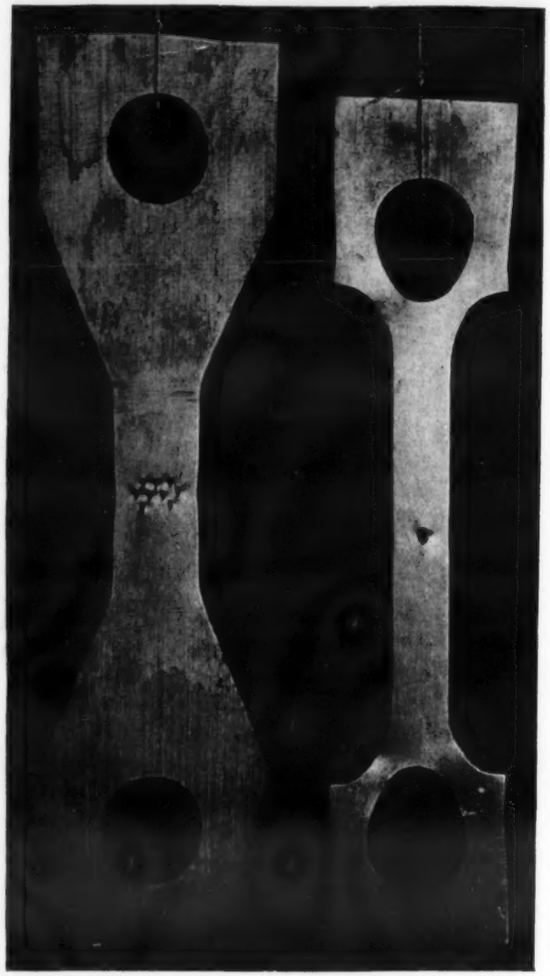


FIG. 16.—Tensile test bars, showing the deformation around the holes.

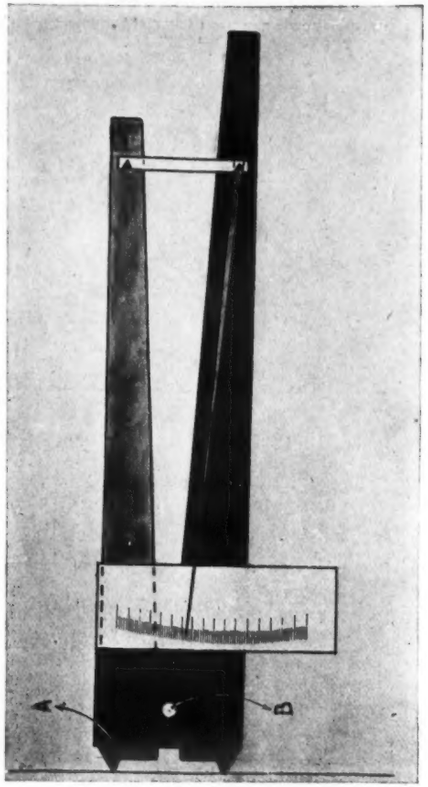



FIG. 17.—Okhuisen-extensometer.
*A* is the centre of the movement of the part at the left side Through *B* an elastic needle is passed to press the instrument on the test piece.

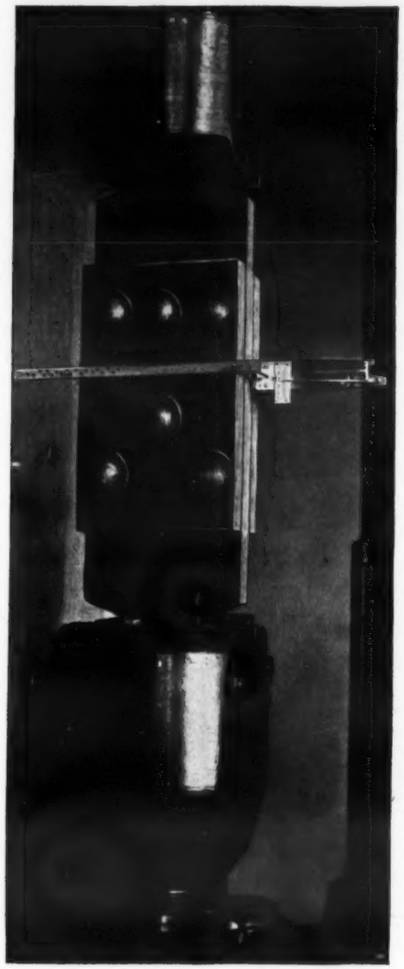


FIG. 18.—Extensometer fastened on the test piece in the tensile testing machine.

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**Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.**

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**We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.**

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—3663 and 8596 GERRARD.


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*With Two One-Page Plates of a* 32-TON ELECTRIC TRAVELLING COALING CRANE, *and Two One-Page Plates of the* FAILURE OF BOILER PLATES IN SERVICE.

## NOTICES OF MEETINGS.

THE SOCIETY OF ENGINEERS.—Monday, October 1, at 5.30 p.m., in the apartments of the Geological Society, Burlington House, Piccadilly, W. A paper entitled "Sewage and its Precipitation; further Experiments" will be read by Mr. Reginald Brown, M.Inst.C.E., M.I.Mech.E., F.S.I., F.R.San.I.

THE CERAMIC SOCIETY: THE REFRACTORY MATERIALS SECTION.—Tuesday and Wednesday, October 2 and 3, a meeting will be held in the Societies' Room of the Royal Technical College, George Street, Glasgow. The President, Mr. W. J. Jones, Ministry of Munitions, will preside. On Tuesday the meeting will open at 10.30 a.m. and the following papers will be read:—"The Distribution and Geological position of the Valuable Fireclays and Ganisters of the South of Scotland," by Messrs. Lionel W. Hinxman, B.A., F.R.S.E., and Murray Macgregor, M.A., B.Sc. "Refractories and Modern Kilns," by Mr. J. G. Maxwell. "The Refractory Properties of Silica," by Messrs. H. le Chatelier and B. Bogitch. "The Testing of Refractories," by Dr. J. W. Mellor. "The Rate of Reaction (Vitrification) of Different Forms of Silica," by Messrs. P. S. Devereux and J. E. Foster. "A Comparison of the Porosity and Contraction of Firebricks made with Wet and Dry Grog," by Miss C. Beveridge and Mr. W. Emery. "The Rate of Hydration of Calcined Dolomite," by Messrs. C. Edwards and A. Rigby. On Wednesday, October 3, the general meeting will open at 10.45 a.m. and at 11.15 a.m. a paper on "The General Organisation of Firebrick Works," by Mr. G. Wink Wight, C.A., Glasgow, will be read. At 1.22 p.m. there will be a visit to the Dalzell Steel Works to inspect refractories in use, and at 6.30 p.m. a popular evening lecture on "The Theory and Practice of Firing" will be delivered by Mr. J. Burton.

THE MUNICIPAL WATERWORKS ASSOCIATION.—Friday, October 5, at 2 p.m., the sixth annual general meeting will be held at the offices of the Metropolitan Water Board, Savoy Court, Strand, London, W.C. The Presidential Address will be delivered and the following papers will be read and discussed:—(*a*) Mr. C. G. Henzell, M.Inst.C.E., &c. (Engineer-in-Charge, Leeds Corporation Water Works), will open a discussion on "Deficits on Water Accounts." (*b*) Mr. R. Kirkpatrick, of the Department of Zoology, British Museum (Natural History), will read a paper on "The Biology of Water Works."

## NOTICE.

**Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal from 6d. to 8d. per copy. This increase dated from and included the issue of Friday, March 16. The change will not apply to unexpired subscriptions.**

### NOTICE TO NON-SUBSCRIBERS.

**In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.**


# ENGINEERING.

*FRIDAY, SEPTEMBER* 28, 1917.


## THE IMPORTANCE OF DETAIL.

IT is little things, small details, which show the thoughtful man, and small refinements which go to make approximate perfection. The man whose mind is always fixed upon the big things is apt to disregard as contemptible the smaller details which *en masse* built up the bigger structure. Houses are made of single bricks, each of which has to be placed; boilers are built by single rivets, each of which has to be closed. So much detail work like drilling holes, screwing home stays, working up single plates, represents the routine by which boilers are materialised. It is never safe to despise the trivial detail, or the daily round and common task, that way lies poor work, inferior production, unreliable goods and undependable men. The mechanical business in all its ramifications consists more in detail origination and improvement, in intensive culture of the little things, than in the conception of big schemes. The opportunity to do something big, whether in design or manufacture—building a railway or a thousand-feet-span bridge or girdling Niagara Falls—comes only to a very few. The responsibilities of the average man are confined mainly to smaller-scale jobs, whose responsibility is similar in kind though differing in degree. Default in the detail, and the big scheme comes to naught; casualty and contingent failure rest more often upon the detail rather than the design.

When the big thing is analysed in competent hands, resolved into its constituent parts, whether synthesis over the drawing board or critical analysis under test, it is found to consist of minutiæ, any one of which may lead to disaster if badly wrought. In this wise engineering effort, metal-working in any field, may with truth be said to be a matter of collective responsibility. Skill in many directions is co-ordinated to achieve a given result; which in turn depends upon the conscientious scruples of many pairs of hands, whose position may not be exalted but whose effort is just as needful.

It takes a big man rightfully to appreciate small detail, and the sooner the small man learns to appreciate the detail for which he is responsible at its rightful worth, the sooner he is likely to rise in position. Nothing, however trivial, cares for itself, someone or other must take interest and charge of the minor as well as of the major matters. It is difficult sometimes for youth to understand this importance of routine and detail, yet without the faithful performance of small tasks and little things it is impossible to qualify for the larger. Some day, when in charge of bigger issues, the troublesome detail remembered in youth, or some trivial experience concerning a little thing, saves endless trouble by such remembrance. The question is emphasised because it is almost impossible to get workmen or apprentices to realise the fact that their responsibility is just as acute and pregnant as ever that of the designer or responsible engineer. Team effort in the sense understood universally in the field of sport provides an exact parallel, default of one man and the game is lost. Under test conditions when a defect reveals itself it is usually found to be the work of the same individual as on the last occasion.

Mechanical art progresses from two distinct sides—assemblage, that is the permutation and combination of known mechanisms tempered with imagination and reason, and from detail improvement. The former demands large experience, originality and the blending of theory and practice, and may be considered as the aspect of the large view and the big thing. The improvement of detail and refinement of process represents a territory in which all may share. It is open to every workman to render services in this connection; there are no mechanics worthy to rank as such who have not at some time or another helped mechanical evolution along its detail path. Indeed, unless the rank and file assist, such improvement is rare, and to them is therefore entrusted this responsibility. Skill consists in the attention paid to minute detail. The art of the mechanic consists in the avoidance of the more obvious, and the performance with certainty of a complex series of processes and small adjustments. Each single isolated point is perhaps not difficult, but the entire series and their mastership constitutes trade skill.

Design in its broadest aspect is built out of detail, and is confined by the tolerances of limitation set by machine, material, process and labour. Yet design separates into big visualisation and provision of detail, and the small part is just as essential as the entire job. There are no redundant parts in mechanism or in the art of metal-working. It is the small thing whose failure leads to breakdown; it is only rarely the device is impossible or vitiated by reason of its overall aspect.

The factor of safety carried is due to two points of ignorance—first, material; second, detail. The factor of safety provides at one and the same time for possible default of material, and also compensates for workmanship errors, otherwise imperfect detail. Where large issues hang upon each single isolated part, default in which must lead at the best to inconvenience and delay, at the worst to fatality, the question of the small thing whose importance is not prominent becomes more realised.

It is in the small rather than the large issue that the average man gets freedom of effort; it is a field not to be contemptuously despised, but is one whose cultivation is apt to be repaid with compound interest. It either leads to larger opportunity, to the building of character, or to that feeling of satisfaction with the labour of his hands that every first-class man enjoys. Work skilfully and conscientiously done, if only in the narrowest of detail fields, represents a broadening of the individual and an independent sphere of action which, if only small, is yet more or less absolute. The facts may be commonplace, the issue little regarded, but no contradiction is possible. Skilled work is just what we make it—either a barrier wall to limit our outlook or a sphere of effort whose possibilities and interest are endless. The former view is that of

(To face page 327.)

the second-rate, the latter that of the competent man. It is realisation of limitation which sets the ingenious planning the extension of the present limits; there is no sense whatever in considering these as eternally fixed. It is in fact the privilege of the mechanical industry that it erects limits only to demolish them again within a short time. This is progress, and there is no need to remind the reader that no industry has altered more, improved more, progressed more in so short a space of time than the activities affected by and located in the skilled mechanical trades.

To-day is the day of small things no less than the time when big things are being done. The two are so interrelated that no analysis can separate them one from the other, action and reaction are equal. The big is impossible without the less, and detail is affected by the demands for reliability and dependence necessitated by huge modern schemes.

Industry is a co-ordinated whole, every worker being a common contributor to the total result; this communal view and the feeling engendered thereby will cut out lots of misunderstandings provided that the facts are realised. The bridge depends upon lots of rivets, each closed by men of grimy hands and hard fingers, and industry in general depends equally and exactly upon similar human factors, never prominent, maybe, but upon whom *en masse* the total rests. National prosperity depends upon industry and agriculture, and the importance of the first to the second cannot be overrated. Incidentally industry rests upon large numbers of workers, each of whom is individually responsible for the total result. It is the little thing properly done which breeds big men, and this is possibly the most important result in any assessment.

## CADETS FOR THE INDUSTRIAL ARMY.

THE prominent position that the science and practice of engineering has taken in the affairs of men during recent years and in the present conflict of nations has once more emphasised the need for a constant supply of recruits from the technical colleges and schools throughout the country to fill eventually positions which have been designated by the term "Staff Officials in Industrial Works." In past years many schemes for the training of qualified engineers have been introduced and debated at the meetings of technical societies and in the columns of the technical press, and, speaking broadly, the outcome of such discussions has been satisfactory, as evinced by the attention that is now being given to the training and education of apprentices and students in various districts. Somewhat naturally the divergencies of thought on this subject have prevented any one scheme from becoming a "standard," each engineering firm adopting such method as seems to apply most fittingly to local conditions. But, after all, the success or otherwise of any system of training depends upon the development of the personal initiative and inherent abilities of the individual—a desideratum which can be fully secured only with the co-operation of the youth concerned.

The old proverb "You can take a horse to water but you cannot make him drink" is frequently apposite in respect of the invitations extended to young men to take the full measure of the benefits and privileges offered to them by their engineering employers, who have instituted courses of study of scientific principles and their demonstration in practice by means of "sandwich" or other attractive and commendable systems of training. "Boys will be boys," and it is always difficult to implant and foster that spirit of emulation which most seniors desire to encourage and stimulate, if only because of their own tardy realisation of lost opportunities. Something is wanted to enthuse the coming generation by self-inoculation, so to speak, and it seems to us that the announcement recently made by the Council of the Junior Institution of Engineers will have a far-reaching effect in this direction.

It is interesting to recall that the Institution referred to was founded thirty-three years ago by a few young men who were completing their indentures of apprenticeship in the Lambeth Works of Maudslay, Sons and Field. Though its present members are of more mature (average) age, it has ever since maintained the original objects of mutual help in technical and social intercourse in a manner which has always been characteristic of "the juniors." This perhaps is mainly a consequence of the automatic infusion of young blood upon its council of management by the operation of a rule which imposes a period of ineligibility upon past councillors. The Junior Institution has always been noted for the manner in which it has beneficially assisted its members in their careers, and by tabulating as it does the experience of individuals, its secretary is generally in a position to put forward from among its 1,400 members the right man for any appointment which an engineering firm may have to offer. It has now extended its sphere of influence, and has instituted a scheme for the registration of students and apprentices in the early years of their training. "Cadet" Associate Members, as they are to be called, are to be registered as such in the books of the Institution for one year, and renewal for further yearly terms is to be dependent upon the certification of "satisfactory progress in the development of their abilities" by a principal or head of department in an approved technical college or school or an approved engineering works.

The scheme outlined by the Junior Institution offers to its "cadets" advice and assistance in all matters concerning their period of training, in obtaining "a good start" when qualified, and in their professional interests generally. It includes the establishment of "groups" in technical educational establishments and engineering works, by means of which there are arranged institutional visits to places of engineering interest; discussion—with the guidance and assistance of senior members—of subjects treated in "papers" read before the parent body or one of its "local sections"; the inculcation of responsibility and resource, under proper supervision, in the control of affairs connected with the group; the encouragement of personal initiative in technical matters; and the development of ability in the verbal expression of thoughts. In fine, the Institution is to give its "cadets" an incentive to utilise to the fullest extent the advantages open to them, and has taken the lead in demonstrating how mutual help may be most usefully applied, and in a manner which will appeal to the latent instincts in those of the younger generation whose serious intention it is to rise in their profession.

In our opinion the "cadet" scheme of the Junior Institution of Engineers should be given the support of all engineering establishments, industrial and scholastic. Those which have their own "engineering society" with similar objects would gain by affiliation in that a broader and less parochial view will then prevail, while the registration as a "cadet" of an old-established society run "by juniors for juniors" could not fail to appeal to the individual in whose interests shop societies are nominally conducted, but who, it is to be feared, now loses interest after a time when the meetings are attended solely by shop associates upon whose merits and demerits certain but somewhat decided opinions have been formed. The fact of being a registered "cadet" of an Institution of wide reputation would engender quite a different spirit, in that an individual would realise that upon his assiduity during his period of training would entirely depend his future opportunities for advancement, and this in a far wider sphere than can possibly be open to him in any one works.

From another point of view, also, the co-operation of works proprietors would seem to be worth while, for the registration of their apprentices as Cadet Associate Members of the Junior Institution of Engineers would enable them to choose their junior staff officers from a much wider field and from certificated sources of no uncertainty. It is indeed the co-ordination of engineering students and apprentices under this scheme which, to our mind, seems destined to make the Junior Institution of Engineers "cadets" an industrial "officers training corps" of exceptional promise for the imminent needs of our national industry.

## THE MINISTRY OF MUNITIONS EXHIBITIONS OF WOMAN'S WORK.

THE series of exhibitions of women's work which the Technical Section of the Labour Supply Department of the Ministry of Munitions has been giving during the past year was continued by one which was opened on the 26th inst. by the Lord Mayor of Sheffield at the Mappin Art Gallery of that city in the presence of the Master Cutler and a considerable attendance. Mr. Ben. H. Morgan, the Chief Technical Adviser of the Department, spoke on behalf of the Ministry, and engineers of his staff will attend daily at the exhibition.

The purpose of these exhibitions is to appeal not only to employers of labour, but to foremen, workmen, and the general public; and in the present instance some of the exhibits of women's manufacture are supplemented by complete machines showing the relation of the parts in the exhibition proper to the finished article, such as a Clerget engine and various machine and other guns and rifles. The large collection of official photographs include, moreover, not only views of women actually doing the work of which specimens are shown, but also engaged on processes on articles that cannot conveniently be introduced into the hall. Some personal interest is also given by photographs of "tanks" (land-ships) actually going into action, and by a small collection of captures from the enemy; and on the two Sunday evenings of the fortnight meetings are to be held at the Don Picture Palace, where, in addition to music and addresses, films will be shown illustrating women at work in French and English munition works, and scenes of active service on naval aircraft, submarines, destroyers, battle cruisers and battleships, with a special film showing "tanks" leading troops into action. The exhibition will be open to the public without charge every day for a fortnight, including Sundays, and those interested in the trade will be able to obtain free tickets for the Sunday evening meetings by application at the Art Gallery.

The exhibits themselves continue, as before, to show improvement on those of the preceding exhibitions, good though they were. They are arranged substantially as before, but additions in the optical group have caused it to be separated from the exhibits of chemical and surgical glassware, and the exhibition is accordingly divided into 15 groups instead of 14. These additions give evidence of steady and remarkable progress in the employment of women on glass-blowing. Specimens are shown of very complex X-ray tubes that women now make successfully, as well as of clinical thermometers, which they now make as well as graduate; and it seems now to be beyond question that they can be trained rapidly to the most intricate glass-blowing work which is required in manufacture. A still more considerable progress is perhaps their employment on the manufacture of incandescent lamp bulbs direct from the furnace. It has been found possible to control the effect of the heat by the use of screens; and it may be hoped that the benefit of this means of reducing the strain in such work may be extended to men, who, even when they can endure the temperature, would be all the better for the relief.

The optical industry is shown by the exhibition as a particularly good example of the rapid and complete introduction of women into a highly skilled manufacture. Before the war they were employed only in one or two factories; but they are now seen to be doing every process in the manufacture (with the possible exception, for the time being, of prisms for superposing two reflections, of which the final working to an accuracy of 5 seconds in 90 deg. is done by highly skilled men) down to the final assembling and adjustment. The collection shown gives, indeed, good *prima facie* ground for believing that the most accurate and delicate mechanical work is well within women's ability; and the belief is supported by results obtained in the other industries that are represented.

Without detailing the several additions that have been made to the exhibits, it may be said that perhaps the most satisfactory feature is the appearance of a new edition of the catalogue, in which the information to which we referred in our notice on July 13 of the Leeds Exhibition is continued and amplified. These exhibitions by themselves would be interesting, as those know who saw that held in London at the Royal Colonial Institute; but the catalogue in the form that has been adopted gives the exhibits an instructional value to the

industries concerned which it would be hard to exaggerate. In the light of it the exhibition appears not only as a detailed evidence of what women can do. It is also for most of the exhibits a record of how they have done it; and in the particulars that it gives it includes details of the subdivision of complex operations in a variety of industries which are applicable not only to the special case of the employment of women, but also to the more general problem of so treating skilled work as to bring it within the scope of persons having only limited skill. This process of subdivision is found in practically all the industries here represented. In some of them it has gone so far as to exceed even the generous limits of space that the catalogue allows. The rear sight of the Vickers machine-gun, with its graduated strip and slide, with its 141 separate operations, or the lock-frame of the same weapon, with 87, may be allowed to be more than can be set out in detail in any reasonable space, and the bare record of the extent of the subdivision and of the fact that the whole of the machining is done by women is quite as much as can be expected. But there are examples enough of subdivision set out in detail and going far beyond what has been usual in British practice. A good specimen is the cylinder of the 160-h.p. aero engine, which is made in 44 separate operations, each of which is named in the catalogue, with its machine, its class of labour, and the time allowed. The much fuller particulars here given justify the hope that even the present edition may be only the forerunner of something still more ample. It is no disparagement of the great work that it has begun to do—indeed it is perhaps the best mark of appreciation that can be given to it—to recognise that it is not yet complete, even in its treatment of its present exhibits; and while it has already collected far more information than most men would have thought possible to procure for publication, it has still a large field to be covered in its future editions. Perhaps it may be found possible more often to supplement the statement of time occupied in individual operations by a statement of the overall time, such, for instance, as is given in the description of the 14 operations used in making the cartridge container for Stokes shell, so that in comparing the practice of subdivided manufacture with that in which one worker does several operations, account may be taken of the time that is spent between the operations themselves. Probably in a shop well enough arranged to allow of this subdivision the total "dead time" will not be a serious deduction from the benefit of the subdivided manufacture; but the apprehension of it is felt by many makers who have not as yet modified their practice, and it would be as well to have such information as would verify or correct it.

But while it is possible to point out details in which the catalogue could be amplified and improved, its appearance and the improvements that have already been made remains a matter of unqualified congratulation to the industries which it interests. It should enable them to increase their present efficiency, and by giving chapter and verse for the advantages claimed for standard repetition manufacture may be a real assistance in determining an industrial policy after the war by which the task of competing in the world's markets may be lightened and be more successfully undertaken. The achievement of the Ministry's technical staff is not, moreover, confined to having collected the information. Perhaps even a more notable contribution to industrial efficiency is that they should have induced so general a disposition in manufacturers to provide it for mutual assistance.

One fact, however, emerges from a comparison of the information given which can only be mentioned with regret. The standard by which the employment of women is regulated, or in other words the efficiency with which the national man and woman power and the industrial skill are being utilised, appears to remain widely variable. The exhibits, for example, of aircraft engines seem to indicate that what in one works is being done successfully by women is debarred to them altogether in others. In all sorts of work, for instance, women in some works are seen to be working on centre lathes to the closest limits of accuracy; yet in others the catalogue records for article after article that they do all the machining except centre lathe work. We have more than once pointed out that engineers cannot be expected to make the most of the human material at their disposal if a uniform standard is not set for the extent to which they are to employ women; and instances such as that just quoted seem to point to their being prevented or unwilling to use it in some cases for purposes to which nevertheless it has been shown to be applicable. It must be understood clearly that unless and until some definite standard is set and applied to all works generally, with exceptions allowed only for mechanical reasons, engineers cannot take responsibility for any failure to make the best use of the national working power. If dilution remains variable, as seems unquestionable on the facts of this exhibition, and if the general understanding that the country is in need of more aircraft than it has is correct, the responsibility for thus inhibiting a well-demonstrated source of increased output is extremely grave.

## NOTES.

### 7,000-H.P. Electric Locomotive for the Pennsylvania Railroad.

The Pennsylvania Railroad Company has recently constructed an electric locomotive with a rated capacity of 7,000 h.p. This has been built in anticipation of the electrification of the line through the Alleghany Mountains, where the heaviest trains now require three steam locomotives to haul them. According to *The Scientific American* the new electric locomotive is 76 ft. long and weighs 240 tons. It is mounted on two eight-wheel trucks. Of the four axles to each truck, three are coupled, the driving wheels being 6 ft. in diameter. Each truck carries two motors, which drive by pinions a large toothed wheel on each side of the truck framing. These large gear wheels carry crank pins, from which coupling rods lead to the pins on the driving wheels. The teeth of the large gear wheels are loose on the wheel centres, to which they are spring-connected. The whole of the drive passes through these springs, which provide an elastic connection between the drivers and the motors. The current is supplied at 11,000 volts on the monophase system, and this single-phase current is, by means of a phase converter mounted on the locomotive, transformed into three-phase current, with which the motors are supplied. Two economical running speeds are provided for, viz., a slow speed of 10 miles per hour with the motors connected in cascade, and a higher speed of 20 miles an hour with all four motors in parallel. On down grades the motors will act as generators, returning power to the line; and heavy trains can thus be controlled without the use of the brakes, which will merely serve as a stand-by.

### Glass Colouring by Radiations.

The well-known fact that ordinary colourless glass assumes an amethyst tint when exposed to intense sunlight for long periods has been turned to practical use by H. Rosenthal, of Camden, New Jersey. In the account of his researches, which he gave to the American Chemical Society at New York in June last, he spoke of experiments in his own laboratory, followed by further experiments made in the laboratories of the General Electric Company, in the Nela Research Laboratories and in the Bureau of Standards; yet the communication seems to be preliminary, unless guarded for business reasons; there is an allusion to a patent. The sources of radiation which Rosenthal uses are mercury arcs and X-ray tubes, the latter of various types and including a self-rectifying Coolidge tube which is worked by currents of 100,000 volts from an oil transformer. The chief tints produced in optical glass were amethyst and amber; green and yellow were also mentioned, and it was stated that the colour could be predetermined when the composition of the glass was known. It was not explained, however, how composition and colour were related. Rosenthal mentioned that his purple and the amethyst colour of manganese glass were not quite the same, and that the changes produced by his radiations were apparently physical, not chemical; he also said that the action was reversible, without stating how—by heating, we suppose. The observations are sufficiently interesting, however. The colour changes due to radiations were said to diminish the transparency of the glass and to distort its spectrum less than when the glasses were chemically coloured; slides were exhibited supporting this statement. The depth of the penetration of the colour change could be varied by using more or less penetrating X-rays; and lenses could be coloured either superficially or throughout their mass. The powerful Coolidge tubes produced in a few minutes changes that would require exposures to sunlight of weeks and months. If it should be generally confirmed that the radiation changes in the glass are able to shield the person wearing spectacles of that glass from the effects of the radiations which produced the changes, important progress would have been made. This seems to be so in the case of sun-tinted glasses, at any rate. Apart from the new glasses recently brought out by Sir W. Crookes and others, the ordinary eye-protecting glasses are smoke glasses, which absorb most of the light they receive, and their relative opacity is a drawback. Various precautions are, of course, already used against X-rays; further protection of the eyes would still be welcome, however. It is also noteworthy that Rosenthal claims to be able to colour porcelain, quartz and precious stones by his radiation process. A shading in the colour tint can be obtained, we should add, by placing optical wedges over the glass to be coloured; in this way artificial teeth and other objects are suitably coloured.

### Magnetisation by Rotation.

The idea that a rotating magnet should behave like a gyrostat if the ampere currents consist in the motion of actual matter is an old one, and Maxwell constructed an apparatus for testing it as early as 1861. The suggestion does not imply, however, that the magnetisation generated by rotation of a magnet should simply be proportional to the angular velocity. For if that were so, laboratory experiments on small magnets at a few revolutions per second should give rise to magnetic forces vastly greater than the terrestrial magnetism and greater than any magnetic forces obtainable by other means. Professor A. Schuster discussed these problems, which had long been occupying him, in his presidential address to the Physical Society in 1912, with special regard to Causes of Terrestrial Magnetism. Since 1909 Professor S. J. Barnett, of the Ohio State University, has been experimentally investigating the subject, and he has given an account of his researches in two long papers published in *The Physical Review* of October, 1915, vol. vi, pages 239 to 270, and of July, 1917, vol. x, pages 7 to 21. Like Schuster and Langevin, he starts from the assumption that rotation only sets up a magnetic force, which may or may not produce magnetisation, and will only do so if the substance be magnetic and therefore constituted of atomic or molecular orbital systems with individual magnetic moments fixed in magnitude. Barnett's orbital systems consist of a number of electrons revolving at constant average velocity in fixed orbits about an oppositely-charged nucleus, and he further considers that the electrons would preponderantly, if not altogether, be negative, as is generally assumed for various reasons. On the electron theory he then shows that a body of any substance set into rotation becomes, by a sort of molecular gyroscopic process, the seat of a uniform intrinsic magnetic intensity parallel to the axis of rotation and proportional to the angular velocity, the intensity being directed—like the magnetisation of the earth and of the sun—oppositely to the intensity which would be produced by an electric current flowing round the body in the sense of the rotation. The intrinsic intensity per unit angular velocity would be $H/n = 4\pi m/e = -7.1 \times 10^{-7}$ gauss, where H is the intensity and $n$ the number of revolutions per second, and $m$ and $e$ are mass and charge of the negative electron. Barnett also discusses the theory of the converse effect, rotation caused by magnetisation, which was established by A. Einstein and W. J. de Haas in their "Demonstration of Ampere Currents" (see ENGINEERING,

August 27, 1915, page 224), and this has since been further confirmed by de Haas in a communication on "Moment of Momentum existing in a Magnet," presented to the Amsterdam Academy, 1916. In his experiments Barnett made use of steel rods, from 2 cm. to 7 cm. in diameter, nearly a metre in length, turned about their longitudinal axes at from 20 revolutions to 90 revolutions (generally about 50 revolutions) per second by an electric motor. In each case two similar rods were observed, the one rotating, the other stationary, and very elaborate precautions were adopted to reduce the effects of the numerous sources of error; there was always, *e.g.*, a slight fluxmeter deflection independent of the direction of rotation. The recent experiments were made with the aid of a magnetometer—not a fluxmeter—on two cold-rolled steel rods about 30 cm. long, 2 cm. or 3 cm. in diameter, and on rods of nickel and cobalt of similar dimensions. Again the results were not very concordant. But whilst the former series of experiments had yielded the average value $H/n = -3 \times 10^{-7}$ gauss per revolution per minute, the new series yielded the coefficient 5 instead of 3, against the theoretical value $-7.1$. In this theoretical estimate it is assumed that only the negative electrons are concerned in the phenomenon; if the positive electrons also had a part the experimental value should be smaller than the theoretical. A smaller value has been found. Barnett considers, however, that the actually observed effect is all due to negative electrons, and that it is too small owing to experimental difficulties. That there is no such effect in non-magnetic metals had already been shown by Lebedew.

## THE INSTITUTE OF METALS.*

### High-Temperature Thermostat.

We reported in our last issue the proceedings at the afternoon meeting of the Institute of Metals, held on September 19 in the rooms of the Chemical Society, Burlington House. The adjourned meeting was resumed at 8 p.m., the first paper down for reading and discussion being one entitled "Further Notes on a High-Temperature Thermostat," by Messrs. J. L. Houghton and D. Hanson. This communication dealt with certain modifications of the instrument brought forward at a previous meeting and described in our issue of October 8, 1915, page 376. Instead of reading the paper, Mr. Hanson briefly explained the working principle of the apparatus described. This apparatus consisted, he said, of a double-walled vessel, similar in shape to a Bunsen ice calorimeter, which was made into a furnace by winding it with nichrome wire. The vessel, he explained, acted as a gas thermómeter, and the variations in the pressure of the air contained in it were used to operate a contact-breaker, which increased or decreased the current supplied to the furnace according as the temperature fell or rose above the desired value. The contact-breaker took the form of a U-tube, containing mercury, fitted with two platinum contacts, which broke the relatively small current of a solenoid relay; this, in turn, pulled a fork into, or out of, two mercury cups, by means of which an external resistance was cut out of, or put into, the furnace circuit. One side of the relay was connected to the furnace bulb; the other to the closed bulb of another thermostat, similar in principle to the main thermostat, but of simpler construction. This arrangement rendered the instrument immune from variations which would otherwise be caused by change of atmospheric temperature and pressure. A device had been added by means of which extremely slow rates of cooling or heating could be obtained; if necessary, of the order of 1 deg. or 2 deg. C. in a day. To use the thermostat for temperatures of the order of 1,000 deg. C. a silica furnace bulb had been constructed, and curves had been taken with the furnace running at about 800 deg. C.

Dr. Hudson was the only speaker in the discussion on this paper. He congratulated the authors on the success of their attempt to produce a really accurate high-temperature thermostat, which would be of the greatest use in future metallurgical research. The device for slow cooling was simple and effective. He would like to observe that the principle of design in the apparatus which the authors had referred to in connection with the speaker's name—probably that set up in the Corrosion Committee's Laboratory at the School of Mines—was to be attributed to Dr. Bengough. The object of this latter apparatus was to run a crucible furnace in conjunction with another furnace controlled by a thermostat such as the authors had described in a previous paper. [Journal of the Institute of Metals, No. 2, 1915, vol. xiv, pages 145 to 149.] Unfortunately it had not been possible fully to test this apparatus, owing to pressure of other work. The results, so far as they went, however, were promising, and the difficulties met with were not connected with the principle of design. The problem of running a working furnace in conjunction with a control furnace was well worth an attempt to solve it. It appeared to the speaker, however, that a double-walled vessel of the type which had been described was hardly that most suitable. It would undoubtedly be a great advantage if some means could be devised for running a crucible type of furnace off a control furnace. The authors had mentioned some attempts to run two furnaces—a high-temperature furnace and a low-temperature glass thermostat furnace—in sequence, and had remarked that the results were disappointing. The speaker would ask if they could give the differences in temperature between the two furnaces; was the control furnace at a much lower temperature than the working furnace? It would be necessary, in running such furnaces together, that the temperature differences should not be great. In the case of furnaces running in parallel, the alteration in the working furnace circuit, in order to give a slow cooling, should tend to be neutralised by the control furnace; but in actual practice he thought the lag of the working furnace would be sufficient to give an extremely slow rate of cooling. Apart from that, the chief difficulty was in getting the working furnace constant in the first place.

Mr. Hanson replied to Dr. Hudson's question as to the attempts made to run the furnaces in series. He and his colleague had endeavoured to run the control furnace—a glass apparatus—at a temperature of 100 deg. to 150 deg. C., the working furnace having a temperature of 700 deg. C. The controlling furnace could have been run at a higher temperature, but the object in view had been to see whether it would work with so great a difference in temperature.

### New System of Gas Firing.

The next paper presented was one on the "Principles and Methods of a New System of Gas Firing," by Mr. A. C. Ionides. We reprint this on page 342 of this issue. Disregarding the paper itself, Mr. Ionides described, with the aid of tables and diagrams, the variables involved in gas firing, and submitted also figures relating to the consumption of gas in Great Britain. From the latter it appeared that in 1916 the production of town gas amounted to 232,474,000,000 cub. ft.; that a ton of coal produced 10,000 to 14,000 cub. ft. of gas; that the annual requirements of the gas industry reached the figure of 23,000,000 tons; and that the coal production of Great Britain was, in 1906, about 250,000,000 tons, the production of coal per man per day being 0.63 ton, or 230 tons per year. The speaker contended, as appears in his paper, that with his system of gas firing a saving of not less than 115,000,000 tons of coal per annum could be effected. A demonstration was then given of the working of the pressure balance apparatus described in the paper. The author next stated that he had been requested by Dr. Bone to say that he (Dr. Bone) disclaimed any responsibility in connection with the figures recorded at a demonstration given on March 19, 1915, at which, as stated in the paper, Dr. Bone was present. As we print Mr. Ionides' paper on page 342 of the present issue, we proceed at once to the discussion.

Dr. Harker, who spoke first, referred to a lecture experiment, probably familiar to members, in which a large-diameter Bunsen burner, provided with a wide glass prolongation tube, was employed. On gradually turning down the supply of gas a change took place in the character of the flame burning at the top of the tube as the gas went through the various phases, from a mixture in which little air was present down to the explosion-point stage. When the quantity of gas was gradually diminished the flame descended, until, at a certain point, the cone—generally well marked when using a wide tube—turned inside out, oscillating at the mouth of the tube. If the experiment were carefully conducted the flame could be made to enter the tube and pulsate slowly at a desired point. The speaker believed that this experiment illustrated what the author had attempted to do, but had not perhaps made clear in his remarks. It was not the mixture usually supplied to a flame that Mr. Ionides wished to burn, but an explosive mixture, whose composition was that which was reached at the point when the velocity of propagation of the flame downwards in the experiment just named was balanced by the rate of feed of the mixture upwards in the tube. In that case a pulsating flame could be obtained, which would remain more or less steady in such a narrow tube as that shown by the author. Mr. Ionides had, apparently, managed to do away with the instability of the flame in his larger scale experiments and had constructed apparatus for burning an explosive mixture in a more or less fool-proof form. If the speaker had understood the author's experiments, the latter had arranged to put all the air he needed into the original mixture, and not, as is more usual, by supplying a part first and subsequently adding the further amount required. Mr. Ionides supplied the air and gas to the flame in such a way that variations in the gas pressure did not cause the extremely unstable flame to jump about, and, in the opinion of the speaker, had effected a real advance in making as part of his arrangement an automatic governor, enabling the mixture to be burnt more or less safely in burners of simple construction. The author had made no allusion to the neat device for preventing lighting back of the flame. His real advance was in the design of comparatively simple apparatus for enabling the mixture of gas to be made with the right amount of air to burn properly, making the mixture independent of variations in the rate of supply of the gas being burnt. Some of the other points mentioned by Mr. Ionides were in the speaker's opinion, only accessory, and he scarcely thought it a matter of significance whether the displacement was downwards or upwards; the essential achievement was the prevention of the backward propagation of the flame in the burning of an explosive mixture.

Professor H. Louis had had the privilege of witnessing the author's experiments at an early stage, and had been impressed at seeing the products of combustion from a furnace in which brass was being melted coming away at a temperature so low that the water condensed as it left the furnace. That appeared to carry utilisation of heat generated further than he had deemed practicable, and gave great interest to the work done by Mr. Ionides. It was well known that there were particular proportions of gas and air mixture at which the maximum heat efficiency would be developed, but much careful work was needed before the theory could be put into practice, and he sincerely

* Erratum.—Dr. A. G. C. Gwyer asks us to make the following corrections to our report of his observations in the discussion on "Annealing Cold-Rolled Aluminium," as reported in our last issue. For the paragraphs commencing at line 26 of the second column of page 312, the following should be substituted: "  .  .  .  .  .  .  and for practical purposes he had assumed that softening had commenced when the tensile strength dropped 0.5 ton per square inch, and this fall might occur over a range of from 40 deg. to over 200 deg. C., according to the purity of the metal, and with especial regard to its silicon content, the influence of iron being of relatively little moment. The speaker showed by means of curves that Professor Carpenter's results were in very close agreement with his own, and also that the abnormality described was characteristic only of high-silicon metal, and entirely absent, within the limits of experimental error, in the ordinary commercial high-purity metal of to-day. The thickness of the metal was important. Thus with 0.25 in. plate the tensile strength began to drop at a temperature of 220 deg. C., but the final state was not reached until 480 deg. C. With the metal rolled to 0.125 in. softening began at a temperature of 130 deg. C., and the final state was attained at 450 deg. C. When 0.064 in. thick the strength fell 0.5 ton per square inch at 80 deg. C. It should be emphasised that the figures quoted were true only for metal of the chemical composition stated, viz., 0.45 Si per cent., and 0.55 Fe per cent."

congratulated the author on his results. There were one or two criticisms he wished to offer. In enumerating the advantages of his system, Mr. Ionides had apparently omitted to debit his appliance with the heat consumed in generating the power necessary to produce the required pressure, a factor which ought not to be left out of account, especially as the whole of the air required had to be forced into the furnace by positive pressure. In the case, say, of a Fletcher injector furnace, only a fraction of the total air had to be forced in, the rest being drawn in by the air jet. Mr. Ionides' apparatus involved a considerable power factor, and the speaker desired to know how the cost of generating that power affected the results. Again, it appeared to the speaker that if air and gas, in regular proportions, were forced in by means of constantly working blowers, the air and gas balance system could be dispensed with. The pressure balance was, he supposed, designed to equalise small fluctuations—fractions of an inch on the water gauge—and in constantly blowing in air and gas—at 10 lb. pressure for example—it would, as he had said, be possible so to regulate the blowers as to do away with any balancing. Perhaps, however, he had misunderstood the principles involved.

Mr. Shipley Brayshaw expressed a doubt as to whether the author was familiar with what had been done by others and with the present state of knowledge on the subjects dealt with. The demonstration given of the ordinary incandescent mantle was, he thought, merely a demonstration of the difference between working with natural draught and working with blast, and a like result could be achieved by any gas manager, who knew the pressure required, without special apparatus. Perfect combustion could not be attained with ordinary gas burners owing to the absence of compressed air; since not enough air was drawn along to produce perfect combustion. With compressed air, on the other hand, it was easy to secure perfect combustion in a small space. With regard to the apparatus for maintaining constant pressure between the gas and the air, that was interesting; but he felt that the claims made for it were too great. The 3-in. pressure balance (3-in. gas mains) had been stated to supply 5,000 cub. ft. of gas per hour, a figure that appeared to him far too high; even if the figure had been placed at 1,000 cub. ft., or as little as 500 cub. ft. per hour, he would have thought it needed close investigation. It appeared to him that the only figures given which were capable of discussion and verification were those which were presented in Table I of the paper. He alluded to this table because his name had been mentioned therein, and because he felt that the figures should not be published as representing what could be done with the system commercially. The construction of the furnace and manner of working it might be suitable for laboratory purposes, but were not, in any conceivable circumstances, adapted for a workshop. The brass was just fused after a long time, and he regarded the results as disappointing; 70 : 30 brass was being melted in the workshops with 2 ft. of gas per pound, and it was safe to say that in this respect commercial requirements were about double those of a laboratory. Again, referring to Figs. 2 and 3 in the paper, which showed the pot marked *c* with the pot *f* standing on it, he had seen this apparatus at work in the laboratory, and noticed that it was furnished with soft asbestos washers between *f* and *c*, to make it gastight, the two pots being held together with pieces of fireclay. Such an arrangement could not possibly be manipulated in a works. Such an apparatus as that of the author, in which an exact balance was maintained, might, the speaker thought, be useful in workshop lighting. He felt certain, however, that gas furnaces would not be successful without recuperation, and recuperation involved different proportions of gas and air from time to time. In conclusion, he regarded the pressure balance as a clever and ingenious contrivance. He believed that Messrs. Keith and Blackman had placed on the market a similar arrangement, which permitted of any proportion between the gas and air—using gas at one pressure, and the air at twice or three times that pressure—and which would maintain the proportion constant.

Mr. W. R. Twigg remarked that, as stated in the paper, he had witnessed a demonstration of the "captive fire" system, and had been impressed with the accurate working of the pressure balance and the ingenious nature of the whole apparatus. He had, however, arrived at no conclusions as to the value of the principle. The tests were not conducted under conditions comparable with those of a workshop, as the previous speaker had urged, and he had therefore made some special tests under similar conditions. In the tests he had witnessed the brass was cast into an ingot of a shape exactly fitting the crucible. The products of combustion were displaced downwards, and other points of the captive-fire system were included. On returning to his works he made tests with a 20-lb. crucible furnace, using the ordinary type of air-blast burner associated with the appliance for which he was responsible. The furnace was of a type similar to those in which to-day brass, gun-metal, nickel and nickel-tungsten alloys were being melted. The results were as follow: On June 26, 1915, the rate of gas consumption per pound of metal was, for the first heat 3.05 cub. ft.; for the second, 2.1 cub. ft.; for the third, 1.95 cub. ft. On the 28th of the same month a further melt showed the gas consumption per pound of metal to be, for the first heat, 3.15 cub. ft.; for the second, 2.15 cub. ft.; for the third, 1.9 cub. ft.; and for a fourth heat, 1.8 cub. ft. On July 15 another test, witnessed by a responsible member of the staff of a large London gas company, indicated the following results: For the first heat 3.5 cub. ft. and for the second heat 1.65 cub. ft. The average of the foregoing results was 3.23 cub. ft. per pound of metal for the first heat, as against an average of 3.13 cub. ft. per pound for the test results given in Table I of the paper; while for the second heat the averages were 1.95 cub. ft., against 1.88 cub. ft. From these tests he concluded that, as pointed out by Dr. Harker, the use or otherwise of downward displacement was an unimportant matter. Finally, he regretted that the author had not brought forward more conclusive evidence in support of the statement that, as compared with existing recognised methods, the captive-fire system would ensure a saving of 50 per cent. of gas in brass melting.

Mr. J. G. Clark observed that he could not have stated, as mentioned in the paper, that with ordinary gas distribution pressures the candle-power attained by ordinary burners averaged 22 c.p. per cubic foot. He could not recall precisely what he had said, but the figures should stand at 35 c.p. to 40 c.p. per cubic foot. The photometer tests shown that evening would, under the existing conditions, be of little importance. Photometry demands great exactitude. The speaker was well acquainted with the candle-power obtained by the air-gas systems. In experiments he had made some seven or eight years ago he had obtained nearly 50 c.p. per cubic foot, and he noticed Mr. Ionides quoted 47 c.p. per cubic foot for his system. Referring to the list of variables given by Mr. Ionides, particularly the pressure in the gas supply, it was inevitable that the gas pressure would vary; there must be loss of pressure, just as there was loss of potential in an electric circuit. This variation of pressure could, however, be controlled by the use of governors. Air-pressure variation could also be regulated by governors, so that a dead constant pressure could be continuously maintained. With regard to atmospheric pressure, the barometer was beyond control, but the pressure of gas, as understood by the gas engineer, meant the pressure of the gas above the pressure of the air. In speaking, therefore, of gas pressure as equal to 3 in., it was to be understood that the pressure of the gas was 3 in. above the pressure of the air. Should the barometric pressure go up $\frac{1}{10}$ in. the pressure would rise at the same time, since it was the difference between the air and the gas that gave what was known as "gas pressure." The upward or downward movements of the barometer did not affect the gas supply.

Mr. L. C. Harvey had brought with him a copy of the paper read by Dr. Thornton at the previous meeting of the Institute, held in March of the present year. From this paper it appeared that, under ordinary methods of burning gas, a consumption of 3.1 cub. ft. was obtained per pound of brass melted. The figures submitted by the author were not much better than that result. He hoped Mr. Ionides would be able to reduce the gas consumption to something like 1.5 cub. ft. or even 1 cub. ft. per pound of metal melted under laboratory conditions. Had Mr. Ionides been able to melt from 200 lb. to 400 lb. of brass, and to submit definite figures of gas consumption for that amount of metal, serviceable deductions might have been made from a practical standpoint. The small furnaces however, were relatively far more efficient than the large ones. In the former case gas could be supplied at a short distance from the orifice of the burner, developing great heat more rapidly and more economically than in the case of large furnaces, with relatively large combustion spaces. The system of downward flow of exhaust gases, referred to in the paper, was not, of course, new, and had been applied repeatedly. The difficulty he had met with in the downward passage of gas was that of getting a refractory material which would stand the heat. Omitting steel melting, he would say that, with a temperature of 1,400 deg. C. inside the furnace, the passage of the gas down the back—unless the wall was of very great thickness—would result in the melting of any refractory material at present known. If heat losses could be conserved by passing the waste gases downwards in the manner shown by the furnace, of course the efficiency of the furnace would be improved; but he considered that the real difficulty resided in the refractories.

Mr. E. P. Sandevin pointed out that the author had referred to the making of a half-ton billet-heating furnace, in connection with which the gas consumption submitted was 1.3 cub. ft. per pound for full forging heat; and that, generally, the author's remarks thereon led to the supposition that this system had been applied to the heating of heavy forgings. The speaker would ask what type of furnace was used, whether or not it was cylindrical and of much the same form as the billet. Further, he inquired whether, as he assumed, town gas was used. British thermal units did not always cost the same amount of money to produce. Assuming the figure of 1.3 cub. ft. above-quoted to represent consumption of town gas, the cost would work out at 0.039*d.* per pound of metal. In the case of a modern producer-gas furnace of the continuous-billet type he had found that 20 tons of billets could be heated with 2½ tons of coal, gasified through a producer. This worked out at 0.02*d.* per pound of metal.

Mr. Ionides contented himself with replying to the questions put by the last speaker, and stated that the furnace used in the case of the half-ton billet was of a type exactly corresponding to the furnace used for the demonstration he had given to members that evening. He might add that the furnace was made by Mr. Twigg, whose firm had been negotiating the possible acquisition of his patents.

### Fuel Economy in Brass Melting.

A paper entitled "Fuel Economy Possibilities in Brass-Melting Furnaces" was next read, in abstract, by its author, Mr. L. C. Harvey. In this paper the author observed that out of the 1,300,000,000 tons of coal raised in 1910 probably not 5 per cent. was turned into real useful work, the remainder being wasted in radiation and other losses. Reverbatory furnaces, for example, were used for producing heavy brass or bronze castings, although much more wasteful of fuel than crucible furnaces, bad as these were, requiring, in short, something like six times the expenditure of fuel which would suffice with tilting furnaces. The use of coke for brass melting was, he said, wasteful and unnecessary, and should be replaced either with powdered coal or unscrubbed producer gas, the preference lying with the former alternative. The author considered that it should be possible to raise furnace efficiencies to 30 per cent. or 40 per cent. by careful design and by utilising the heat of the waste gases. Electric crucible furnaces had, the author observed, efficiencies of as much as 75 per cent. Town gas had been very successfully used for brass melting during the past three years. It was convenient, clean, and prolonged the life of the crucibles, but it was not in other respects economical. Producer gas was much superior in this regard, but was

unsuitable for use in small plants. Oil fuel was excellent from the technical standpoint, and would be generally used were it not for its prohibitive price. The superiority of tilting furnaces as compared with pit furnaces was mainly due to the use of higher-grade and quicker-heating crucibles, and to their larger capacity. On the other hand, the pit furnace, taking smaller crucibles, is unsurpassed in regard to the quality of the metal. In view of this fact the author submitted designs for an improved pit furnace, in which special attention had been given to the reduction of heat losses. We shall produce these designs in a future issue, when we publish the text of Mr. Harvey's paper.

Mr. A. S. Brayshaw opened the discussion, observing that the author, after setting out the advantages of using powdered coal, and after stating that the efficiency of the coke-fired crucible furnace was about 15 per cent., had expressed the hope that efficiencies of 30 per cent. to 40 per cent. might be reached by careful study and application of improved methods of combustion and utilisation of the heat carried off in the waste gases. In this connection the speaker remarked that, obviously, gas could be burnt a great deal more efficiently than coal, whether the latter were powdered or not. Gas lent itself to efficient burning; it could be burnt in smaller spaces, the radiation losses would be smaller, and gas also lent itself to recuperation, which coal did not. Moreover, in urging the use of the coal in a powdered form in gas works, Mr. Harvey had not apparently considered the question of by-products.

Captain G. D. Bengough said that the author, in calculating the efficiency of his furnaces, had stated that 261 British thermal units were required to melt 1 lb. of 70 : 30 mixture, and to superheat the alloy to 10 per cent. above melting-point. The speaker could understand that the superheat would have so many degrees, but could not appreciate the meaning of the expression "10 per cent. above its melting-point." Further, he assumed that the various efficiencies given in Table I of the paper were based on the figure 261 British thermal units quoted in the foregoing statement, and he would like to know how Mr. Harvey had obtained that figure. Captain Bengough was not aware of any direct experiment having been made to determine the absolute amount of heat required to melt 1 lb. of brass or copper, or any other non-ferrous metal. Before the efficiency of a furnace could be determined it was necessary to know how much heat was likely to be required to melt 1 lb. of the metal under consideration. At present the only available data for the calculation were those determined by Richards and Percy, and Dr. Harker and others, for the specific heats of metals, and from those data the calculation had to be made indirectly. The speaker had worked out the figures, but found that, instead of 261 British thermal units, only 230 British thermal units were needed to melt 1 lb. of metal, according to the constants for copper and zinc given by Percy and Richards. It would be of use to the Institute if some definite figure could be given, with which the coking efficiencies of the various furnaces could be compared. Doubtless Mr. Harvey's efficiencies were comparable with one another, but not with efficiencies quoted by other authors of papers. In conjunction with a colleague, who had been killed in the early stages of the war, Captain Bengough had carried out considerable research work to find, using the direct method of melting by means of electric current, exactly how much energy was required to melt 1 lb. of copper to the melting-point, and, thereafter, up to 1,100 deg. C., giving a superheat of 140 deg. The results of his research inclined him to criticise Mr. Harvey's figures. It had been impracticable to complete the work, but apparatus had been constructed that closely approached, he believed, one suitable to give an absolute figure for the amount of energy required to melt 1 lb. of copper or of any suitable alloy. He wished to say that he could place a large amount of work at the disposal of any member who desired to carry on the research with the object of obtaining the figure required. Should any member be desirous of continuing the investigation, it might save him some months of labour if he would communicate with the speaker at the Royal School of Mines.

The hour being late, the president closed the discussion at this point, and stated that the remaining papers on the programme, namely, that by Professor Zay Jeffries on "The Effect of Great Hydrostatic Pressure on the Physical Properties of Metals," and that on "The Use of Chromic Acid and Hydrogen Peroxide as an Etching Agent," by Mr. S. W. Miller, would be taken as read.

The proceedings terminated with a vote of thanks, proposed from the chair, to the Council of the Chemical Society for their courtesy in permitting the use of their rooms.

## 21-IN. HOLE CRANK-FORMING LATHE.

WE illustrate this week, on page 334, a 21-in. crank-forming lathe constructed by Messrs. Thomas Ryder and Co., Limited, of Bolton, a firm who have for many years devoted much attention to the production of machines for finishing motor and other crankshafts. The tool illustrated is a single-pin forming machine, and was developed as a natural sequence to the duplex machine formerly made by the firm. The duplex machine was very successful in its day, but it was not readily adapted to deal with changes in the design of crankshafts, and this led to the production of the single machine.

The particular machine shown by our engravings is capable of dealing with a crankshaft of which the length measured over the outside webs of the outer cranks, plus the length of the longest end, does not exceed 4 ft., and of such dimensions that it will swing in a circle 20 in. in diameter. The height of centres is 18 in. and the hole in the spindle is 21 in. in diameter. The machine is intended to finish the crank-pins and down the sides of the crank-webs, the main journals of the shaft having been previously finished to size.

As will be seen from Figs. 1 to 4, the design of the bed is very substantial, and has the cross-slide cast solid with it. At the end of the bed is fixed an extension piece, of closed-box section, on which the loose head-stock is mounted. The driving head is arranged so that the machine can be driven either by belt or by a constant-speed motor, the power being transmitted through steel gear machine-cut from the solid, and the final drive to the spindle being through a pair of double-helical gears. Six changes of speed are provided, only those gears which are actually transmitting power being in mesh. The changes of speed are controlled by the upper left-hand lever and the hand wheel seen on the front of the machine in Fig. 1, while the power cutting feeds to the tool slides are regulated by the lower left-hand lever shown in the same view. The feeds provided for are four in number.

A special feature of the design is that the two tool slides are operated simultaneously. When the pin being operated upon is approaching its final diameter the front tool is put out of gear and the back finishing tool finishes the pin. By this means much time is saved as compared with the usual practice of employing only one tool at any time. The tool slides are arranged to trip automatically at predetermined positions when the final diameter is controlled by hand-feeding the finishing tool to a dial indicator. In practice it is found quite possible and easy to finish a pin to any given size, and, if necessary, to reduce the diameter of the work with precision by as small an amount as 0.001 in. To avoid the really hard labour and loss of time involved in winding back the heavy tool slides, a quick-acting power return motion is fitted, this motion being controlled by the lever marked in Fig. 1. As will be seen from Fig. 3, the two tool posts are firmly bolted down to the carriage slides, and the whole design is very rigid. The movement of the slides is effected by large-diameter screws made of high-carbon steel fitted with long phosphor-bronze nuts.

Inside the main drive or spindle there is mounted a sliding head carrying an adjustable work-holder, adapted to receive the end of the crankshaft which is to be machined. This work-holder, which will be seen in Fig. 2, is under control by a hand wheel with pointers showing the correct position for any throw of crank. On the front of the drum is mounted another adjustable work-holder, also provided with pointers to show its correct position. This latter work-holder grips the main bearing or pin of the crankshaft which happens to be next that which is to be machined, while the loose headstock supports the outer end of the crankshaft. The crankshaft is thus held in two bearings and supported at the end, while the drive is transmitted close up to the cutting tool.

Splash lubrication is provided for all the main driving gears, while the main bearings of the spindle are fitted with sight-feed lubricators, and the other bearings of the driving mechanism with ring lubricators. A complete self-contained pump and tanking system is provided to ensure an efficient supply of lubricant on the work.

Figs. 5, 6 and 7, on page 334, together with the data tabulated below, will give a general idea of the speed at which pins can be formed in the machine we have been describing, the work produced being true to diameter and cylindrical within 0.001 in. of size. It will, however, of course, be understood that the machining time occupied in the case of any crankshaft depends upon the material of which it is made, as well as upon many points in the design of the shaft itself.

| Type of Crank-shaft. | Average Cutting-Speed. Feet per Minute. | | Feeds. Inches per Revolution. | | Actual Machining Time per Pin. Minutes. |
|---|---|---|---|---|---|
| | Down Sides | When taking Full Width Cut. | Down Sides. | When taking Full Width Cut. | |
| Fig. 5 | 43 | 27 | 0.030 | 0.005 | 10 |
| Fig. 6 | — | 20 | — | 0.005 | 3 |
| Fig. 7 | 42 | 27 | 0.030 | 0.005 | 15 |

WATERPROOF AND DUST-PROOF FABRICS.—The skin which forms on the surface of some oil paints and varnishes is practically air-tight. According to a paragraph in the *Zeitschrift des Vereins Deutscher Ingenieurs* of July 21, 1917, such a skin, which is at any rate waterproof and dustproof, can be formed on sacks of jute and on bags of cardboard, &c., for the transport of lime, chalk, cement and dextrine, as well as for packing greasy and oily materials. The process is described as the Plüss-Stauffer process, but there are no further particulars; it is merely stated that the skin is pressed upon the material, which need not be a texture, by special machinery.

JAPANESE IRON AND STEEL INDUSTRY.—We read in *The London and China Telegraph* that a law for the protection of the iron industry has been submitted by the Japanese Government to the present session of the Diet. If enacted, it will extend the privilege of importing iron free of duty not only to the Oriental Iron Company, now being projected, but also to similar works being organised by the Mitsu Bishi as well as to the Japan Steel Works. Other enterprises for the manufacture of charcoal, pig-iron, and electrolytic steel in larger quantities than 10 tons a day will be similarly entitled to the protection of the law.

SILICA EXAMINATION BY RÖNTGEN RAYS.—In the study of firebricks and other refractory materials it is advisable, but difficult, to ascertain in which state the silica is present, whether as quartz, or as quartz glass, cristobalite or tridymite. This examination can, according to S. Kyropoulos (*Zeitschrift für Anorganische Chemie*, June 12, 1917), be made by the X-ray method of Debye and Scherrer, which we noticed on page 17 of our issue of July 6, in an article on the "Structure of Matter." Kyropoulos powders the material to particles of 0.5 $\mu$. or 1 $\mu$, fills the powder into cylinders made of tissue paper, 2 mm. in diameter, compresses the powder so as to obtain a coherent rod, and exposes it to the Röntgen rays for about three hours. The photographs which are reproduced in the paper show the black central spots surrounded by dark, wide or narrow rings, which differ in intensity and in dimensions for the different forms of silica; the differences between amorphous and crystallised silica are particularly striking; there is evidently a mistake in the numbering of the diagrams, however, which will be explained in a subsequent issue of the journal, we expect. The experiments were made with quartz, cristobalite, quartz glass (fused silica), precipitated hydrated silica, containing 19 per cent. of water, as prepared, and after heating to 1,300 deg. C. for two hours, finally, a silica gel, containing 89 per cent. of water, prepared five years previously.

EXTENSION OF GERMAN INDUSTRIAL UNDERTAKINGS.—The firm of Robert Bosch has recently started a concern in Stuttgart for the manufacture of small machines and apparatus, with a capital of 12,000,000 marks, and the firm's branch at Feuerbach has been extended and transformed into a limited company, with a capital of 1,200,000 marks. The company will make a speciality of rolling, pressing and drawing processes.—The Stralsund Overland Central has raised its capital from 7,000,000 marks to 12,000,000 marks. The company, which was started in the year 1912, with a capital of 2,430,000 marks, has already several times increased its capital.—The Bavarian Overland Central, Haidhof, has increased its capital from 2,500,000 marks to 3,500,000 marks.—Under the style of the Central Baden Railway and Electricity Company, a company has been formed in Baden with a preliminary capital of 3,000,000 marks; the main object of the company is to exploit the energy from the State hydro-electric power station, Murg. Amongst the founders are the towns of Karlsruhe, Bruchsal and Rastatt, besides the Rhenish Schuckert Company and the Electric Power Supply Company in Mannheim. The new company's district comprises 170 parishes.—At the instance of the National Bank for Germany a manufacturing and trading company has been formed which, principally, will devote its work to mining undertakings and the production of industrial raw materials of all descriptions.—A new concern has been founded in Anhalt for the purpose of carrying on lead, silver and wolfram mining, more especially the latter, which at present is very valuable. The new undertaking takes the form of a *Gewerkschaft*, and is styled Pfaffenberg.—Another new mining undertaking has secured all the shares of the Altley *Gewerkschaft*, for the purpose of carrying on zinc and other mining at Zell-on-the-Moselle.

## INDUSTRIAL NOTES.

THE President of the Local Government Board is anxious that all possible steps shall be taken to reduce hardship in the cases of sole proprietors of businesses who through the Nation's necessities have to join the colours. He is convinced that the best way of doing this, consistently with the legitimate claims of the Army, is by co-operation among traders; and he appeals strongly to traders who remain in civil life, whether they are of military age or above military age, to assist in this matter, so that their fellow-traders who have to leave their businesses in order to serve the country may do so with the assurance that their business interests will, as far as possible, be protected.

The solution of the problem rests mainly with the traders themselves; and if they will but co-operate wholeheartedly to solve the difficulties much can be done. Enough has already been achieved in various parts of the country to show that co-operation for the maintenance of a man's business is practicable to a very large extent if goodwill and an earnest desire to render all reasonable assistance to the man who has been called to serve his country are forthcoming. It is not practicable to lay down any one scheme for the whole country; the measures which may be advisable in any particular case depend on the local circumstances, and it is the men who are conversant with the businesses concerned who are the persons best qualified to determine in what way help can best be given.

Mr. Hayes Fisher has appointed Mr. R. A. Rotherham, the chairman of the Local Tribunal for Coventry, who has been active in pressing forward co-operation for safeguarding the interests of men who have joined the Forces, as a Special Commissioner to visit localities and generally to assist the Board in forwarding schemes of co-operation.

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Inquiries have been made as to whether the decision of the Minister of National Service to discontinue the local National Service Committees includes the Substitution Trade Committees consisting of representatives of associations of employers and operatives.

We are authorised by the Secretary of the Ministry of National Service to state that there is no intention of discontinuing any of the Trade Committees. These committees have done, and are doing, valuable work, and the Minister hopes to receive their assistance in an increasing extent in the future.

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The Employment Department of the Ministry of Labour, Queen Anne's Chambers, Westminster, S.W. 1, has issued a statement dealing with the organisation and work of labour exchanges, and with the constitution of Local Advisory Committees. There will be in general, says the statement, one committee for each exchange, and its advisory function will include the consideration of any matter arising in connection with the working of the exchange. One of the spheres in which it is hoped to obtain great assistance from the committee is in connection with the provision of substitutes for men to be released for the Army. It is proposed that they should also perform important functions in connection with the resettlement of labour on demobilisation.

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The Minister of Reconstruction, Dr. Addison, speaking last Saturday at Huddersfield, said that whatever steps might be taken in dealing with problems of reconstruction, it was quite certain that reliance must be put in the main on people helping themselves. But the Ministry of Reconstruction filled a need, and he instanced the efforts being made by the Germans in different parts of the world to get the supply of material and products which our people would want. The efforts of the German Minister of Reconstruction had to be counteracted. When the war ceased, he added, the unemployment problem ought not to be so formidable as it looked. Certainly over a million men who were fighting would have their places kept for them. Another large class would be required on shipbuilding and on the railways at home and abroad. In many trades there would be large demands, but the carrying out of orders necessitated the provision of raw materials. The shortage of materials had been aggravated in some commodities by the shortage of ships, and the more the traders did for themselves to remedy it the better he should be pleased. He proposed to consult the different trades as to the best way of doing it. The traders should associate themselves together as far as possible to help the Government.

In the past, Dr. Addison continued, this country had not made enough use of brains. How highly trained scientific men had overcome the difficulties of supplying our armies could never be sufficiently expressed, and yet those men had been paid salaries, in some cases by people who ought to have known better, that were a disgrace to the community. One lesson of the war had been that it paid to employ brains, and to pay them properly.

Only by increased productivity, Dr Addison further said, should we be able to overcome the devastation caused by the war. We could do it, but we needed four things. Our first and most important need was better co-operation between Capital and Labour; secondly, we needed better conditions of life; thirdly, better training; fourthly, better industrial methods. In regard to the first, he believed the committee presided over by Mr. Whitley, M.P., which suggested a form of labour and employers' councils, had great possibilities for usefulness. They should get together and form some machinery for the settlement of differences. Until that was done we could make no real progress in increasing output. Labour should be entitled to a share in the benefit of increased output. Labour should also be protected against cutting rates. The fear of unemployment was largely responsible for hostility to improved methods. That had got to be removed. One could not expect a man to put his heart into improved methods which might throw him out into the street. The general questions of the conditions and hours of labour would have to be settled in some way before we could get increased output.

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In his speech in the House of Commons on August 15 the Minister of Munitions stated that he hoped that negotiations concerning the rates of pay of certain time workers would be completed within four to six weeks from that date, and that Leaving Certificates would then be abolished.

These negotiations are now in course of completion, and Mr. Churchill has fixed October 15 as the date on which the abolition of Leaving Certificates shall come into effect. This will give time to enable the necessary administrative measures to be taken in order to avoid as far as possible any dislocation which may follow the abolition of the certificates.

Among other safeguards against excessive migration of labour, the War Munitions Volunteer scheme has been extended to enable men eligible for enrolment who are working away from their homes to enrol as War Munitions Volunteers and receive subsistence allowance on the usual War Munitions Volunteer conditions, if allocated to the establishments in which they are working. Men who have already enrolled and are working away from their homes, without having been allocated by the Ministry, may also receive subsistence allowance on the same conditions if allocated to their present establishments.

The following appeal to all munition workers has been issued by the Trade Union Advisory Committee:—

"On October 15 Leaving Certificates will be abolished, and workmen will be free to leave for other work after giving their employer a week's notice, unless a longer period is provided by their existing contracts of service.

"If large numbers of men leave their work suddenly, and a big movement of workpeople takes place, there is danger that the output of urgent munitions may be dislocated, and the men at the front will suffer.

"We therefore appeal on behalf of the Trade Union Advisory Committee to all workmen not to change their employment without definite and substantial grounds, and to show that the output of munitions will not suffer by the abolition of Leaving Certificates."

Then follow points which the men are requested to consider, bearing in mind that the output of munitions depends upon them.

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An article from an occasional correspondent published in a recent issue of *The Glasgow Herald*, and entitled "Labour and the War," makes very interesting reading. He says that if employers of labour fail in the performance of their various duties after the war is over, it will not be for want of exhortation. The wonder is that a body of men deemed to be so much in need of instruction should have been able to carry on the industries of this country with a certain amount of success, not to say in a manner which evokes the admiration, probably the envy, of the men of industry in other countries. Prominent among the censors and instructors are, of course, the Parliamentary orators. The average Member of Parliament cannot be accepted as a competent authority on the adjustment of the remuneration of labour. The correspondent from which we quote continues to say that the Munitions Act, framed in a hurry, contains a threat to any employer who shall, after the war, employ a non-union workman. After we have finished our present struggle against oppression a freeborn Briton may be punished for employing a fellow-citizen on terms mutually agreeable to the contracting parties. At the present time the payer of wages has hardly any voice in the fixing of them.

One of the latest exploits of the Committee on Production was to bestow in certain industries an advance of 5s. per 54 hours on piece-workers and time-workers indiscriminately, without inquiry into piece-work rates and in face of the recent agitation for payment by results only. They ignored the complication of dividing 60 pence over 54 hours. More recently they have pressed an advance of 3s. per week on men who were already earning 3s. per hour. Articles and addresses teem with vague aspirations for the new heavens and the new earth, but so far as the correspondent can discern, the materials for the new celestial and terrestrial business premises are to be found by the employers.

Among the suggestions so freely offered is one that the employees be given a voice in the management. This is too vague; such a demand could only be dealt with if a definite plan were submitted. Capacity for business management is none too widely distributed, and its appearance in the ranks would be eagerly sought for and encouraged by speedy advancement. In regard to the claim, held by some as the birthright of the workmen, for "a greater share in the profits," the correspondent states that the whole profits of a business belong to those who are responsible for the losses and to no other person whatever. The wage-earner compounds for a share of the earnings of a factory in the shape of a fixed rate of wages, and these wages are a first charge on the assets. The reports of the census of production show how comparatively small the fund is out of which, after paying wages, the salaries of managers, the rents, royalties, rates, taxes, depreciation and other expenses, and profits, if any, have to be paid, and nothing can be more senseless than the envious clamour for the share in the reward of ability from those who have been given priority in the receipt of earnings.

Payment by results is strongly advocated, but the efficacy of the system in increasing output is to be entirely nullified by the payment of a minimum wage. The Prime Minister seems to think, adds the correspondent, that the stimulating effect on output of a piecework system is quite a recent discovery, but he rather inconsistently repeats the old wheeze that the good workman is systematically robbed of the fruits of his diligence by a prompt reduction in the rate of pay. He says "that has been the great folly of the past, and that is why the fear of these piece-work rates has simply bitten into the workmen's mind." Of course accusations of employers require no proof—at all events none is ever forthcoming, doubtless for the best of reasons."

The correspondent says, further, that he has not been able to discern the least sign of any Minister having learned that the duty of every trade union which would justify its existence is to aim at the reduction of the cost of manufacture and transit of the products of its trade. Unless these can be delivered in foreign markets at lower cost, of equal or better quality than the corresponding products of other nations, foreign trade cannot exist.

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THE NEW QUEBEC BRIDGE.—The operation of lifting into place the central span of the new Quebec Bridge, which was in progress when we went to Press last week, was successfully completed on Thursday afternoon last. The work was commenced on Tuesday and extended accordingly over three days. The weight of the span is about 5,000 tons, and the height of lift 150 ft.

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THE UNITED STATES SHIPBUILDING PROGRAMME.—The United States shipbuilding programme put before Congress is divided into three parts. A total of 433 ships, of about 2,000,000 tons, have been contracted for at a cost of 285,000,000 dols. A further number of 452 ships, of about 3,000,000 tons, are ready to be contracted for at a cost of 455,000,000 dols. Besides these, 237 ships, of about 1,280,000 tons, are under negotiation, at an estimated cost of 194,000,000 dols.; 150 miscellaneous vessels, of about 1,800,000 tons, account for 300,000,000 dols. Organisation and various other outlays total 35,000,000 dols. The sum authorised by Congress on June 6 amounted to 550,000,000 dols., of which 300,000,000 dols. are appropriated. The sum to be authorised for the building programme immediately in sight, making no allowance for changes in cost of material and labour, is 719,500,000 dols. The amount required for commandeered ships is 515,000,000 dols. Of this total 250,000,000 dols. has already been authorised by Congress, leaving 265,000,000 dols. to be authorised by Congress. The cost of vessels to be purchased, outside those under construction or commandeered, is 150,000,000 dols. Congress is to be asked for a total amount of 1,134,500,000 dols. for ships to be purchased, in addition to the amount already authorised.

| | Dols. |
|---|---|
| For commandeered vessels ... | 265,000,000 |
| For the construction of new vessels ... ... ... ... | 719,500,000 |
| For the purchase of new vessels... | 150,000,000 |
| Total ... ... ... | 1,534,500,000 |

The sum desired to be appropriated for the remainder of the fiscal year 1918 is 915,000,000 dols., made up as follows:—

| | Dols. |
|---|---|
| For commandeered vessels ... | 365,000,000 |
| For the construction of new vessels ... ... ... ... | 400,000,000 |
| For the purchase of new vessels... | 150,000,000 |
| Total ... ... ... | 915,000,000 |

## STANDARD TAP HEADS.

WE have received from the Sheffield Engineers (Small) Tool Manufacturers' Association the subjoined list of standard sizes of the square heads of engineers' and pipe thread taps. These sizes have been adopted by the association named, and the table will be useful to many of our readers.

*Sheffield Manufacturers' Standard List of Tap Squares.*

| No. of Square. | Size of Square. Fraction. | Size of Square. Decimal. | Whitworth Thread Taps. | International Thread Taps. | Gas Tap. |
|---|---|---|---|---|---|
| | in. | in. | in. | mm. | in. |
| 0 | $\frac{3}{32}$ | 0.109 | $\frac{1}{4}$ | 3 to 3½ | |
| 1 | $\frac{3}{32}$ | 0.140 | $\frac{3}{16}$ | 4 to 4½ | |
| 2 | $\frac{5}{32}$ | 0.156 | $\frac{7}{32}$ | 5 | |
| 3 | $\frac{1}{4}$ | 0.203 | $\frac{1}{4}$ | 6 to 7 | |
| 4 | $\frac{1}{4}$ | 0.234 | $\frac{5}{16}$ and $\frac{3}{8}$ | 8 to 10 | $\frac{1}{8}$ |
| 5 | $\frac{5}{16}$ | 0.281 | $\frac{5}{16}$ | 11 to 12 | |
| 6 | $\frac{5}{16}$ | 0.312 | $\frac{3}{8}$ and $\frac{7}{16}$ | 13 to 14 | $\frac{1}{4}$ |
| 7 | $\frac{3}{8}$ | 0.390 | $\frac{3}{8}$ and $\frac{1}{2}$ | 15 to 17 | $\frac{1}{4}$ |
| 8 | $\frac{3}{8}$ | 0.453 | $\frac{3}{8}$ and $\frac{1}{2}$ | 18 to 21 | $\frac{1}{4}$ |
| 9 | $\frac{3}{8}$ | 0.546 | $\frac{3}{8}$ and $\frac{1}{2}$ | 22 to 23 | |
| 10 | $\frac{1}{2}$ | 0.640 | 1 | 24 to 26 | $\frac{3}{8}$ and $\frac{1}{2}$ |
| 11 | $\frac{1}{2}$ | 0.718 | 1 | 27 to 30 | |
| 12 | $\frac{1}{2}$ | 0.812 | 1 | 31 to 33 | $\frac{3}{4}$ and 1 |
| 13 | $\frac{1}{2}$ | 0.843 | 1 | 34 to 36 | |
| 14 | $\frac{1}{2}$ | 0.906 | 1 | 37 to 41 | 1¼ |
| 15 | 1 | 1.078 | 1¼ and 1½ | 42 to 46 | 1¼ and 1½ |
| 16 | 1 | 1.203 | 1½ and 2 | 47 to 52 | |
| 17 | 1 | 1.375 | 2 and 2½ | 54 to 58 | 2 and 2½ |
| 18 | 1 | 1.500 | 2½ and 2¾ | 60 to 64 | |
| 19 | 1 | 1.625 | 2¾ and 2¾ | 66 to 70 | |
| 20 | 1 | 1.750 | 2¾ and 3 | 72 to 76 | 2½ to 3 |

NOTES.

Intermediate diameters have same squares as sizes below.

The heads of fluted hand reamers have same size squares as Whitworth taps and international thread taps respectively.

The sizes of squares are stated in fractions, and in decimals of inches, to facilitate measurement with either the mechanics' rule or the micrometer calliper.

No. of square may be quoted when ordering tap wrenches.

## THE WORK OF THE NAVY ON THE TIGRIS RIVER.

AN interesting despatch from Captain Wilfrid Nunn in connection with the operations of H.M. gunboats in Mesopotamia, from December, 1916, to March, 1917, has been issued, and once more establishes the courage and great resource of the officers and men of the Navy. No recognition, however, is given to those who, in the design and construction of the gunboats, made possible the great success of these naval operations, which contributed so much to the taking of Bagdad and the advance northward of that city. Of the 16 gunboats which took part in the attack, 12 were designed and built by Messrs. Yarrow and Co., at their works on the Clyde, and the four others were from the design, but built by other contractors. It would have stimulated the workers in these yards to know definitely that their work had directly helped so materially in the naval campaign in Mesopotamia. We are glad to note that the artificers who were in charge of the machinery are recommended for special mention, promotion, honours and awards. Among these are: Chief Engine-room Artificer H. Lovell, of H.M.S. Tarantula; Stoker Petty Officer Edward S. Crossman, of H.M.S. Mantis; Acting Chief Engine-room Artificer, 4th Class, William J. Hollis; Stoker Petty Officer George T. Hasler, and Stoker John Farrell, R.N.R., all of H.M.S. Moth; Stoker Petty Officer John W. Mallinson, of H.M.S. Snakefly; Engine-room Artificer, 2nd Class, Leonard Ernest Brown, of H.M.S. Gadfly; and Engineer Lieutenant-Commander Stanley W. Cooke, lately of H.M.S. Proserpine. The King has also made several awards, and the following, among others, have received the Distinguished Service Medal: Chief Engine-room Artificer H. Lovell, Chief Engine-room Artificer, 2nd Class, Alexander Greig; Acting Chief Engine-room Artificer, 4th Class, William J. Hollis; Engine-room Artificer, 2nd Class, L. E. Brown; and Stoker Petty Officers Edward Crossman, G. T. Hasler, John W. Mallinson, and John Farrell, R.N.R.

## CORROSION OF CONDENSER TUBES.

TO THE EDITOR OF ENGINEERING.

SIR,—Now that Mr. Cumberland explains (see his letter on page 277 of your issue of September 14) that mechanical and chemical agencies only cause corrosion through the intermediary of electrolysis, I am in perfect agreement with him. Your other correspondent, "C. de F. M.," however, stated that electrolysis played no part; his contention being that the action was purely mechanical and chemical, meaning apparently erosion and simple chemical solution; an idea which is surely a myth. It reminds me of an old fitter whose explanation was to the effect that metal only corroded when it was "perished," whatever that meant.

If Mr. Cumberland will glance through my article on "Propeller Corrosion," in ENGINEERING of May 24, 1912, and the letters following, he will observe that I am quite alive to the influence of mechanical stress in initiating galvanic action. It is also emphasised in my article on "Condenser Tube Corrosion." I am, with Mr. Cumberland, of opinion that it has a greater importance than most people imagine, but it is only right to point out that in most cases the strains set up in deformed or worked metals can be removed by annealing, so that corrosion from this origin can be largely avoided. I am afraid I cannot enlighten Mr. Cumberland much about the installation on his principle to which I referred. I believe it was due to the late J. B. Hannay as a development of his "Electrogene," but I am not certain on this point, or whether it was discarded by order of the Board of Trade or not; neither can I remember whether the external current was supplied from a dynamo or a battery—shall I say, from a mechanical or a chemical source? The principle involved, and the general arrangement of the anodes, were the same as Mr. Cumberland's, with the exception that the anodes were iron and not aluminium. Within the last few days an engineer of world-wide repute told me that he was interested in a similar system fitted in an Atlantic liner about the same period, possibly it is the same to which I referred. Over fifty years ago Clark introduced his electric "anti-incrustator," which also depended on a counter E.M.F., but the current generated was so small—if it ever was generated—that it was a complete failure, although at the time the inventor claimed great things for it. Since then processes involving the use of a counter E.M.F. have been fairly frequent.

I have only seen one of Mr. Cumberland's installations, and as it had not then been put into commission I could only form an idea of its probable efficiency. Some time or other I hope to have the privilege of inspecting one which has been operating for some time. Personally, I do not quite see the necessity for so high an E.M.F. as he employs. Two or three volts, with provision for sufficient current density, should, in theory at any rate, do all that is required; excess current can only wear away the anodes unduly and generate gas without performing any useful work.

For theoretical purposes it is sometimes convenient to assume that polarised electrodes are coated with films of oxygen and hydrogen, but if the boiler shell is actually coated with hydrogen in Mr. Cumberland's system it raises the very important question of the occlusion of the gas by the steel and its consequent embrittlement. The possible accumulation of explosive gas in the steam spaces should also receive consideration.

It is certainly correct to say that no metal or alloy is incorrodible, but some of the newer alloys resist the action to such a degree that when used under suitable circumstances they may, for practical purposes, be considered incorrodible.

Yours faithfully,
WILLIAM RAMSAY.

23, Sycamore-road, Higher Tranmere, Birkenhead,
September 26, 1917.

## NATIONAL ASSOCIATION OF ENGINEERING FOREMEN.

TO THE EDITOR OF ENGINEERING.

SIR,—It will interest a large number of your readers, also your correspondent, Mr. H. Greenly, to learn that a meeting has been convened for Saturday, October 6, at 4.30 p.m. at the Cannon-street Hotel, Wellington Room.

It is hoped to elect a committee to draft rules, &c., for the general conduct of the association and to appoint delegates to wait upon the Commission appointed by the Minister of Munitions.

In the interest of all engaged in the engineering trades, including pattern-makers, foundrymen and smiths, it is hoped that a good number will make it convenient to attend, and we trust to see many friends from the provinces and outlying districts.

I am, sir, yours faithfully,
H. E. BUTCHER.

273, New Cross-road, S.E. 14, September 24, 1917.

GRAIN STORAGE IN SWEDEN.—According to the *Stockholms Dagblad* the Swedish Commissioners for Warehousing and Cold Storage have requested the Government to allot 3,675,000 kronor (out of the recent Parliamentary grant of 8,000,000 kronor) for the building and equipment of 12 grain storages in different parts of the country. (18 kronor = 1*l.*, par rate.)

SUB-STATION ATTENDANTS.—The twelfth course at the Northampton Polytechnic Institute for giving a preliminary training to disabled sailors and soldiers as sub-station attendants has just been completed, and a number of the men are awaiting vacancies. Engineers of supply undertakings having vacancies are invited to communicate immediately with Dr. R. M. Walmsley, principal of the Northampton Polytechnic Institute, Clerkenwell, London, E.C. 1.

TRADE SCHOLARSHIPS FOR BOYS, 1918.—The London County Council offers about 260 trade scholarships to boys between the ages of 12½ and 16 years whose parents are resident in London. The scholarships provide free education (with maintenance grants ranging from 6*l.* to 15*l.* a year), for one, two, or, in certain cases, three years at trade schools approved by the Council. The instruction provided at these schools is designed to enable boys on leaving school to take up either apprenticeships or employment in skilled trades. Instruction is given in motor-body building, the engineering and allied trades, building trades, furniture and woodwork trades, book production, silversmithing, photo-engraving and photo-process work, professional cookery (to train boys as chefs) and professional waiting (to train boys as waiters). Application forms (T. 2/258) and full particulars of the scholarships may be obtained from the Education Officer (T. 2), London County Council Education Offices, Victoria Embankment, W.C. 2, to whom all applications must be forwarded not later than Saturday, October 13, 1917.

## PRINCIPLES AND METHODS OF A NEW SYSTEM OF GAS FIRING.*

By A. C. IONIDES.

THE author's method of heating with gaseous fuel dates from June, 1909, when he was carrying out an experiment preliminary to constructing a calorimeter for testing the calorific value of petrol air-gas. The experiment was to ascertain whether or not the flues could be downwardly displaced in a calorimeter, in order to avoid any possible loss of heat.

At that time silica glass was a new material, and it so happened that a little prior to this date this material was exhibited for the first time at the Royal Institution. A test tube, about ½ in. inside diameter and 6 in. long, and a piece of $\frac{1}{16}$-in. bore silica glass tube about 8 in. long, were acquired. Connecting one end of the silica-glass tube to the petrol air-gas by means of rubber tubing, the author ignited the mixture, and was astonished to find that it burnt, and continued to burn, in the upper end of the inverted test tube. Moreover, as the silica glass became hot, the flame either disappeared or became invisible, and the character of the combustion altered. The changed state of combustion continued indefinitely, and suggested that there should be no difficulty in transmitting the greater part of the heat units of the gas to the object to be heated. This experiment may be said to have established the fact that flues may with advantage be downwardly displaced.

The first problem that presented itself in applying this new principle was the difficulty of establishing and maintaining a constant mixture. There are three main variables to be dealt with as regards mixture: (1) The inlet pressure of the air; (2) the inlet pressure of the gas; (3) the variation in consumption of either air or gas that may occur in any given installation.

This first problem was the most difficult of all to solve, since, for domestic purposes, &c., it was necessary to deal with differences of pressure sometimes involving a consumption of, say, 2.7 cub. ft. of gas per hour. Nevertheless, after a lapse of four years, this problem was solved by the construction of a device now known as a pressure balance.

It has been suggested that a better name would be a "mixing balance," and the author concurs in this view. This balance (Fig. 1) consists of a sensitive bell 4, with a requisite length of seal. The inside of this bell is subjected to the static pressure of the gas, and the outside to the static pressure of the air. It will be seen from the figure that when the static pressure of the gas increases, the arrangement is such that the flow of gas cuts itself off, and the flow of air is, to some extent, increased; and likewise, when the static pressure of the air above increases it shuts itself off, and opens the gas correspondingly, and *vice versa* when the gas and air are decreased. And, it is to be observed, a similar cycle of operations takes place when the consumption of the one or the other is increased or decreased. Therefore by such a device the pressures of gas and air are always held in a constant ratio, whatever be the variation of either the inlet pressure of gas or air, or the consumption.

If a mixture of gas and air be rich in gas, the flame is correspondingly lengthened. On the other hand, if the proportions approach 6 or 7 volumes of air to 1 of gas (according to the quality of the gas), it is quite possible, given silica or any other good catalyzer, to have no flame at all, but merely surface combustion. Now these conditions present great difficulties in heating with a neutral mixture—one which may be said to be neither oxidising nor reducing—because of the tendency to local heating; and before this was finally and satisfactorily solved another three years had passed.

Should a good catalyzer be placed at right angles to a stream of well-proportioned mixture, a glowing disc will be observed. On the other hand, if all catalyzers in front of this stream are avoided, the combustion can be spread out to a very considerable length. The author has proved by experience that with a ¾-in. injector, or even with one of ½ in., it can be spread out to a length of 3 ft. of almost homogeneous combustion, by putting the injector into a channel of firebrick opened at the top, as in Fig. 2. In this way the heat units can be distributed in a furnace, or boiler, or any other heating apparatus, in a very satisfactory manner.

The third point in the system under description resulted from an observation that the hotter the furnace grew the less was the consumption of gas. By taking into consideration the expansion of gases by combustion, some light is thrown on this phenomenon. What happens if the mixture enter the furnace at, say, normal temperature, 15 deg. C.? Obviously, if it act as a perfect gas, it will have expanded $\frac{1,700}{273 + 15}$, or 5¾ times its initial volume.

If the waste gases, instead of passing into a chimney open at the top, are displaced downwardly through a contracted exit of predetermined cross-sectional area, this will cause a resistance to the flow of incoming gases and provide the elements of the most refined thermostat, without any working parts. In fact, by these means the temperature to be maintained can be predetermined with a pencil and a piece of paper.

The fourth problem was how to determine the mixture. After many trials it would seem that the simplest plan is to fit an ordinary gas cock with a piece of copper tubing bent with an easy bend and enlarged at the farther end, and screwed into the injector in such a manner that the enlarged opening at the end of the copper tubing faces the central axis of the delivery pipe, in this way avoiding stream lines. Now, if a piece

* Paper read before the Institute of Metals, Wednesday, September 19, 1917.

of india-rubber tubing and an incandescent mantle be fed with this mixture, the light will indicate the character of the mixture. If the meshes of the mantle are visible, it means an oxidising mixture. If, however, the mantle is at its most brilliant point, the mixture will be very near the neutral point. On the other hand, if any unburnt gas is seen to escape from the mantle in the shape of a blue flame, the mixture will be an excessively reducing one. There is a further variable to which reference has not yet been made, and that is the quality of the gas. This can be provided for by external distribution. Let it be assumed that there is a mixing balance on the air and gas mains entering into a factory, and that all the injectors in the factory are properly calibrated and set for their various functions—brass-melting, steel-heating, illuminating, &c. When an unwelcome change in the quality of the gas occurs it is immediately visible on one of the lights. A regulating cock on the air main (preferably a screw-down tap) will at once put this right, and the whole of the factory will be compensated for this change in the quality of the gas.

*Advantages of Employing these Principles.*—From what has already been said, it will be readily seen that the conditions of conducting heat operations of many kinds on these principles are cleanly, and extremely economical in fuel. But the economy is not only in fuel, but also in forgings. There is specially notable the facility with which a reducing or an oxidising flame can be established and maintained, thus ensuring a consequent absence of scaling. Manufacturers have informed the author that they often have to scrap as much as 90 per cent. of their steel forgings owing to scaling. The figures given by perhaps the largest users of furnaces for steel forging in Europe, after testing, for five months, a furnace for forging machine-gun barrels, were :—

Saving, 50 per cent. to 55 per cent.
Scaling, negligible.

Therefore it is perhaps unnecessary to state that, even if there were no economy in fuel, there would still be a great saving with regard to steel forgings. A ½-ton billet heating furnace has been made, and the figures given with respect thereto were —

Gas consumption, 1.3 cub. ft. per pound for full forging heat.
Scaling, negligible.

In Table I is given a list of figures relating to 70 : 30 brass, melted in a 20-lb. crucible furnace. These figures speak for themselves, and show that in brass-melting an economy analogous to that afforded in steel forging can be effected. It might be added that Messrs. Vickers applied this system to a barrel-heating furnace 36 in. by 12 in. by 3 in. inside, which resulted in their coming to an agreement to establish this system throughout their works.

As an indication of the correctness of the principles employed, the author would point out that a light worked by means of a pressure balance feeding a small incandescent mantle will produce 130 c.p. to 150 c.p., with a consumption of under 3 cub. ft. per hour of town gas of standard calorific value ; whereas it can be stated, on the authority of Mr. J. G. Clark,* that the highest candle-power light obtainable at this pressure by other systems averages 22 c.p. per cubic foot of gas consumed (variable, of course, owing to the atmospheric burner).

To show the saving to the country that would be brought about by use of these devices, it may be recorded that :—

1. A 3-in. pressure balance saves 50,000 cub. ft. of gas, or 5 tons of coal per 10-hour day, compared with a Brown and Sharp furnace, which is considered by all small arms factories to be the best on the market.

2. One thousand of these devices, in the manufacture of which 240 tons of combined iron castings and steel sheeting would be required, would save in six months—i.e., 180 ten-hour days—the gas distilled from 900,000 tons of coal.

3. Should the barbarous use of raw coal as fuel, which in itself is most wasteful, be discontinued, and this system be found to be equally economical with all forms

* *Gas Journal*, May 4, 1915.

TABLE I.—GAS CONSUMED IN A 20-LB. CRUCIBLE FURNACE MELTING 70 : 30 BRASS.

| Date. 1915. | Lb. of 70 : 30 Brass Melted. | From Cold. | | Second Heat. | | Third Heat. | | In the Presence of |
|---|---|---|---|---|---|---|---|---|
| | | C. Ft. Gas. used. | C. Ft. per Lb. | C. Ft. Gas used. | C. Ft. per Lb. | C. Ft. Gas used. | C. Ft. per Lb. | |
| 30 Jan. | 12.56 | 42.0 | 3.36 | — | — | — | — | Dr. Harker, of the National Physical Laboratory. |
| 2 Feb. | 15.0 | 51.0 | 3.4 | — | — | — | — | Mr. J. S. G. Thomas and Mr. Dean Chandler, of the Metropolitan Gas Company. |
| 3 ,, | 16.0 | 52.0 | 3.25 | — | — | — | — | Professor Louis, of Newcastle. |
| 15 ,, | 20.0 | 66.0 | 3.3 | — | — | — | — | Messrs. Fletcher, Russell and Co. |
| 24 ,, | 16.0 | 60.0 | 3.75 | — | — | — | — | Mr. A. A. Anderson, of the South Metropolitan Gas Company. |
| 26 ,, | 19.0 | 55.5 | 2.89 | — | — | — | — | Mr. Charles Clare, Mr. Singleton and Mr. Wilkins, of Fletcher, Russell and Co. |
| 19 Mar. | 20.0 | 55.0 | 2.75 | — | — | — | — | Mr. H. J. Yates, |
| 19 ,, | 19.75 | — | — | 40.0 | 2.1 | — | — | Mr. A. S. Brayshaw, and |
| 19 ,, | 14.0 | — | — | — | — | 27.0 | 1.92 | Professor Bone. |
| 29 ,, | 20.0 | 58.0 | 2.9 | — | — | — | — | Messrs. J. and J. Braddock, of Oldham. |
| 30 ,, | 20.0 | 53.0 | 2.65 | — | — | — | — | Mr. Hilton, representative of Messrs. J. and J. Braddock. |
| 30 ,, | 20.0 | — | — | 36.0 | 1.8 | — | — | |
| 30 ,, | 14.0 | — | — | — | — | — | 2.08 | |
| 19 Apl. | 20.0 | 56.0 | 2.8 | — | — | — | — | Messrs. Keith and Blackman (Mr. Angus). |
| 27 ,, | 20.0 | — | — | 41.8 | 2.09 | — | — | Messrs. Keith and Blackman (Mr. Keith and Mr. Angus). |
| 20 May | 19.5 | 77.5 | 3.98 | — | — | — | — | Mr. Davis and Mr. Twigg, of the Davis Gas Stove Company. |
| 27 ,, | 20.50 | — | 2.83 | 19.25 | 2.0 | 18.50 | 1.86 | Mr. Twigg and Mr. Gray. |
| 21 July | 20.0 | — | — | 28.5 | 1.4 | — | — | Mr. Reeson, of the Gas Light and Coke Company. |
| 14 Sept. | 20.0 | 56.0 | 2.8 | — | — | — | — | Mr. Arthur H. Kelday, Superintendent of the Commercial Gas Company, Stepney Green. |

Fig.1. MIXING BALANCE.

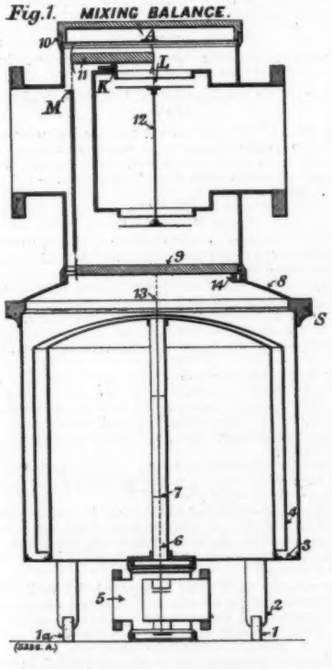



FIG. 1.—Mixing balance. 1, 1a, levelling screws ; 2, feet ; 3, bell container ; 4, sensitive bell ; 5, gas-valve box ; 6, gas connection to bell ; 7, bell-rod guide ; 8, cover to container ; 9, main beam ; 10, cover to air-valve box ; 11, secondary beam ; 12, double-beat air valve ; 13, chain attachment to beam ; 14, fulcrum for main beam.

CRUCIBLE FURNACE.

Fig.2.

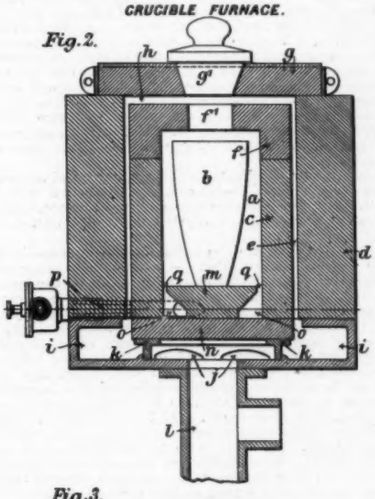
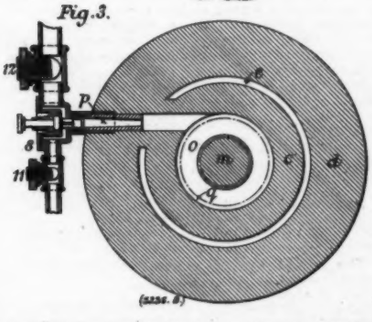



Fig.3.




FIGS. 2 and 3.—Crucible furnace. *a*, furnace chamber for containing a crucible ; *b*, crucible ; *c*, inner walls ; *d*, outer jacket ; *e*, flue space in between outer and inner jacket ; *f*, collar with central aperture *f*1 ; *g*, cover with movable plug *g*1, resting on outer jacket *d* ; *h*, space between *f* and *g* forming a communication through the aperture *f*1, so that the combusting gases vent themselves downwards through the annular space *e*, and pass thence through the hollow platform *i*, by way of the aperture *j* in the central supporting ring *k*, to the downward discharge pipe *l*.

Fig.4. RECTANGULAR BARREL FURNACE.

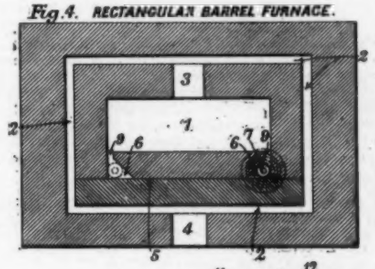
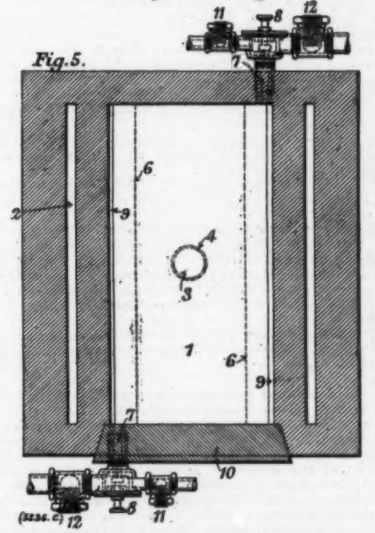



Fig.5.




FIGS. 4 and 5.—Rectangular barrel furnace. A heating chamber 1, having a door 10 at the front, is provided above and below, and, upon the greater portion of its sides, with jacketing flue spaces 2. The chamber 1 communicates by one or two central apertures 3 with the top flue space, and the heating elements passing through the said apertures pass downwards through the flues 2, and are finally discharged through the outlet pipe 4. In the bricks 5, forming the floor, there is provided along each of the two long sides a narrow combustion chamber 6, into which a nozzle 7 delivers mixture from a mixing device 8, provided with gas and air-adjusting means, 11 and 12. The long combustion chambers 6 each deliver the products of combustion by a long narrow slot 9 into the furnace chamber 1. The nozzle is positioned at one end of the long combustion chamber, so that the heating elements, due to their travel along the chamber and their upward motion to escape through the slot 9, enter the furnace chamber 1 with a diagonal movement parallel to the wall thereof. The gases passing along the wall will tend to turn at the angle when meeting the adjacent wall, and thus a whirling motion of the gases round the walls of the chamber will be created. If the nozzles for the two combustion chambers are arranged at opposite ends of the furnace, as shown, this whirling will be accentuated, the gases being gradually drawn inward across the roof of the furnace chamber on their way to escape at the outlet aperture 3.

of producer-gas as with town gas, then in this country alone, where 250,000,000 tons of coal are raised every year, these devices would save half this coal; or, in other words, they would double the industrial possibilities of England.

## METALLURGICAL AND MECHANICAL PRACTICE IN OPEN-HEARTH STEEL WORKS.

As mentioned in our last issue, the Iron and Steel Institute appointed a committee to deal with the above-named subject. The committee was constituted as follow:—Chairman: Mr. George Ritchie. Vice-chairmen: Mr. A. J. Capron, Mr. E. H. Saniter. Other members: Mr. C. J. Bagley, Mr. A. Lamberton, Mr. M. Mannaberg, Mr. Vernon Abbot, Mr. W. F. Beardshaw, Mr. H. Brearley, Mr. P. B. Brown, Mr. D. F. Campbell, Mr. J. J. Cohade (Le Creusot), Mr. F. W. Cooper, Mr. T. Crosby, Mr. E. Crowe, Mr. P. N. Cunningham, Mr. J. H. S. Dickenson, Mr. R. Gray, Mr. E. C. Greig, Mr. D. M. Maclay, Mr. J. MacFarlane, Mr. W. Simons, Mr. M. L. Simpson, Mr. C. P. Williams and Mr. J. Williams.

At the meeting of the Institute held on the afternoon of Thursday, the 20th inst., the committee submitted two reports, which we subjoin, and these reports led to a discussion, which is reported in our article dealing with the meeting and appears on page 324 of, the present issue. The two reports are as follow:—

### PRELIMINARY REPORT OF THE METALLURGICAL SECTION OF THE COMMITTEE.

#### COMPARISON OF OPEN-HEARTH PRACTICE AT HOME AND ABROAD.

The committee having decided that an investigation of the causes of the much smaller output of steel obtained from British furnaces as compared with foreign practice would be of value, issued the following list of questions, with the hope of elucidating the matter:—

*Questions.*

1. Are you acquainted with foreign open-hearth practice in: (1) The United States; (2) France or Belgium; (3) Germany?

2. If so, do you attribute the larger outputs per furnace to: (*a*) Nature and proportion of raw materials used; (*b*) process employed; (*c*) size of furnaces; (*d*) special design; (*e*) general lay-out; (*f*) producer practice; (*g*) labour conditions; (*h*) management; (*i*) grade or quality of product produced?

In answering the above questions, please give as much detail as possible in explaining reasons for increased output, also give dimensions and drawings when possible. In stating output, a convenient way is to state: (1) Tons per week per 100 sq. ft. of bath area*; (2) number of casts; (3) whether basic or acid steel is produced; (4) whether cold or molten metal is charged; (5) working hours per week.

3. Are there any other points not covered by the above list which, in your opinion, account for the larger output of foreign furnaces?

4. In current British practice, which, in your opinion, are the factors in the foregoing list which chiefly affect the output?

5. Do you know of specific instances where output has been increased in existing furnaces as the result of slight changes in design or operation: (*a*) In the furnace itself; (*b*) ports; (*c*) regenerators; (*d*) valves; (*e*) gas quality and supply; or (*f*) any other change?

6. What changes in design or operation have had such an effect?

7. Please state any general views which may bear on the subject. Drawings showing any change in design found to realise the objects in view would be of great value in this connection.

Seventeen sets of answers have been received, and the best thanks of the committee are due to those firms and gentlemen who have responded to their inquiries. The committee are still open to receive further answers or any information or drawings which may assist in the solution of the question. It was considered, however, that by bringing a preliminary report before the Institute the information already obtained could be disseminated and discussed with immediate advantage. The following preliminary report, which it was thought better to retain in the form of question and answer, has been compiled from the answers received:—

2. Do you attribute the larger outputs per furnace in foreign countries to: (*a*) Nature and proportion of raw materials used; (*b*) process employed; (*c*) size of furnaces; (*d*) special design; (*e*) general lay-out; (*f*) producer practice; (*g*) labour conditions; (*h*) management; (*i*) grade or quality of product produced?

(*a*) *Nature and Proportion of Raw Materials Used.*—There is general agreement that in foreign practice the proportion of scrap used, up to 80 per cent., helps output very materially in cold-charged basic open-hearth practice, if used in conjunction with suitable pig-iron, which is generally low in phosphorus and silicon, of which the following is the approximate analysis:—

| Silicon. | Sulphur. | Phosphorus. | Manganese. |
|---|---|---|---|
| (Not over 0.75) | 0.05 | 0.15 | 2.0 to 4.0 |

For hot metal it does not appear necessary to have so low a phosphorus, as shown by the following analysis:—

| Silicon. | Sulphur. | Phosphorus. | Manganese. |
|---|---|---|---|
| 0.4 | 0.06 | 1.8 | 1.25 |

The silica in the limestone and ore used should be as low as possible. Sandless pig-iron is also most important for cold charging.

(*b*) *Process Employed.*—While there is a feeling that certain modified open-hearth processes in conjunction with molten metal increase output, there remains the fact that when one compares, say, for a concrete example, the basic open-hearth process with the same process in Germany, our output is less than half theirs. The process employed is therefore not a deciding factor.

(*c*) *Size of Furnaces.*—When furnaces of the same size are compared our output is greatly inferior as compared with abroad. At the same time, in comparing two so-called 50-ton furnaces it will generally be found that the foreign furnace is the larger.

(*d*) *Special Design.*—The question of special design is illusive, and yet we believe very important. The steeper pitch of the air ports, and an angle of 30 deg. for the gas, with long, shallow furnaces, are indicated. One firm suggests preparing a standard design, and offer their plans. No doubt others would do the same, and it is the intention of the committee to carry out this suggestion.

The use of a basic back lining right up to the roof is mentioned as an advantage.

(*e*) *General Lay-out.*—There is a general consensus of opinion that there is a great superiority in foreign lay-outs. The importance of the influence on output of the regular working of machinery and the supply of raw materials, together with the rapid and easy removal of the ingots, slag and rubbish, cannot be exaggerated. This can only be obtained with a good general lay-out, which makes the management easier and encourages the men, through the absence of delays, to do their best. The committee propose to go further into this matter and make recommendations.

(*f*) *Producer Practice.*—There is a general opinion that the gas producers are a source of loss of output in this country, and that more care is devoted to them abroad. (1) In order to economise fuel it is necessary to make a good gas with low $CO_2$, say, not exceeding 5 per cent. (2) In order to produce the best output of steel, it is necessary to have an abundant and regular supply of good gas under 10 per cent. of $CO_2$. Careful supervision is necessary to attain these two objects, but it is better to have No. 2 if No. 1 is unattainable owing to insufficient supply of gas from the plant available.

(*g*) *Labour Conditions.*—There is a general agreement that our labour conditions, as compared with the Continent, are detrimental to output. It is not, however, suggested that this is due to inferiority of the men individually.

The following are the points on which stress is laid: (1) In this country there is a shorter working week. This is doubly hurtful to the output, in that the furnaces are cooled down more at the week-end and consequently take longer to recover their full heat. (2) The objection of the men as a body to promotion by merit. (3) The lack of close attention and obedience which should be given by such highly paid men. (4) This might be improved if careless workmen understood that they would immediately lose their jobs, but this is rendered almost impossible by the men as a body, except in cases of very gross carelessness. (5) It is well known that the men can turn out more steel when they put forward their best efforts. (6) There is no doubt that the high wages paid should command the best men, and that these men should do their utmost to secure the maximum output, but we fear that owing to the attitude of the men in protecting carelessness these extremely high wages have an effect in the opposite direction and reduce output, as the careless man can make as much as he wants without effort.

The following is a comparison of melters' earnings in several countries before the war:—

*Earnings per Shift (pre-war Figures).*

| | English. | American. | German. |
|---|---|---|---|
| | *s. d.* | *s. d.* | *s. d.* |
| First hand ... | 36 11* | 17 4 | 9 6 |
| Second hand | 24 9 | 11 3 | 7 0 |
| Third hand ... | 18 5 | 9 9 | 5 6 |
| Total ... | 80 1 | 38 4 | 22 0 |
| The weight of steel made per shift is approximately in the ratio of ... | 1 | 1.5 | 2.0 |

* The figure of 36*s.* 11*d.* is given as an average, but it may be stated that in many cases the shift earnings ran as high as 45*s.*

(*h*) *Management.*—It is not considered that the melting-shop management, except in so far as it is impeded by lack of the best facilities and good discipline, is materially worse than abroad.

(*i*) *Grade or Quality of Product Produced.*—It is generally agreed that the stricter specifications required from the poorer raw materials have an impeding effect on output.

3. Are there any other points which, in your opinion, account for the larger output of foreign furnaces? The following have been put forward as additional contributing causes of larger outputs abroad: (*a*) Improvement in refractories; (*b*) use of larger tap-holes to reduce time in tapping; (*c*) less time occupied in fettling and cooling the furnaces for fettling; (*d*) quicker charging.

4. In current British practice, which, in your opinion, are the factors in the list in Question 2 which chiefly affect the output?

First importance: Labour conditions, raw material, special design, general lay-out.

Second importance: Producer practice and grade or quality.

While we place the various matters in the above order, we recognise they are so interdependent that it is difficult to realise an advantage by altering one condition without giving attention to the effect of the others.

5. Do you know of specific instances where output has been increased in existing furnaces as a result of slight changes in design or operation: (*a*) In the furnace itself; (*b*) ports; (*c*) regenerators; (*d*) valves; (*e*) gas quality and supply; (*f*) any other change?

6. What changes in design or operation have had such an effect?

The following express the general view: (*c* and *d*) By increasing regenerators, flues, valves and chimney. In one case improvement has been produced by reducing the height of chequer work to 26 courses. Also by having easy lines of flow in the flues. (*b*) By raising the back end of ports. By reducing size of ports, a 15-in. by 17-in. gas port having been found sufficient for an acid furnace 32 ft. 6 in. by 14 ft. inside brickwork. By arranging ports so as to concentrate flames nearer to block. (*e*) By improving quality and supply of gas. (*f*) Special method of working basic open-hearth charges of all molten metal. Very little limestone and oxide are put in the furnace before the metal. After the molten iron is charged, rapid and continuous feeding of oxide and lime is practised, causing the first impure slag to flush off. By this method a 50-ton charge has been tapped in 7 hours 20 minutes from starting to charge.

7. Please state any general views which may bear on the subject of the inquiry.

Few English firms realise the importance of making the most suitable pig-iron for the steel works.

We look upon the question of labour as a most important one. The wages are so high that it is useless to expect men to make extra exertion to gain more. It seems, therefore, that in order to increase the output it is necessary to reduce the effort required from the workman by every possible means, and this can only be done by a well-laid-out and well-organised plant. Output might also be improved by getting better educated sample-passers and foremen, and by encouraging more highly educated men to go in for melting. When one considers the very handsome remuneration this should not be difficult.

### PRELIMINARY REPORT OF THE MECHANICAL SECTION OF THE COMMITTEE.

#### COMPARISON OF ROLLING-MILL PRACTICE AT HOME AND ABROAD.

The committee issued the following list of questions in order to obtain the views of manufacturers as to the causes of the smaller output of steel in British steel works as compared with foreign practice:—

*Questions.*

(GROUP I.)

1. With a view to ascertaining the possibilities of increasing output and reducing cost of production, can you please give any information on the following points?

(*a*) As to the effect of specialisation of products in foreign or British practice.

(*b*) As to the use of continuous finishing mills.

(*c*) As to the proportion of the total working hours lost to output by reason of changing rolls in your different mills.

2. Please name any points you may have observed in the design and construction of foreign rolling mills which you consider material in increasing output.

3. Why is the three-high plate mill with continuously running flywheel and motor not in more general use in this country?

4. What is your opinion as to the best types of manipulators for: (*a*) Cogging; (*b*) billeting; (*c*) finishing sections; (*d*) slabbing?

5. What, under general conditions, do you consider the best method of driving, electrical or steam, the following classes of mills: (*a*) Reversing mills—cogging; finishing; plate mills; (*b*) continuously running bar and merchant mills?

6. Is output materially influenced by difference in conditions of labour abroad and in this country, giving any instances and particulars?

(GROUP II.)

7. What is the maximum cost per unit of current at which installation of electric drive is warranted for reversing, cogging and finishing mills? Please give any information you can as to the number of units consumed per ton of material, giving sizes and elongation.

8. Can you give any figures as regards weight of steam used in high-pressure or compound engines per ton of finished product in stated elongation?

9. What is the present position of the large gas engine for generation of power or for blowing? State your experience of such engines, saying under what conditions of gas and steam supply you would still install them.

10. Is turbo-machinery displacing the gas engine for either of those purposes?

11. Give what figures you can regarding the cost of generation of current by blast-furnace and coke-oven gas, including all costs, and stating the method of generation.

NOTE.—The intention, in submitting the above questions, is particularly to ascertain the main causes of the relatively small output obtained in many cases in this country compared with foreign practice.

*Question No.* 1.

1. With a view to ascertaining the possibilities of increasing output and reducing cost of production, can you please give any information on the following points: (*a*) As to the effect of specialisation of products in foreign and British practice; (*b*) as to the use of continuous finishing mills; (*c*) as to the proportion of the total

* Bath area being area inside brickwork at sill level.

working hours lost to output by reason of changing rolls in your different mills?

SUMMARY OF REPLIES.

(*a*) In this country a rolling mill has to turn out a large variety of sections, instead of as in the United States and German works, where they employ three, and sometimes four, mills for what is done here in one mill. One of the causes why mills here are smaller in productivity than on the Continent and in America is the fact that rolling to gauge and finish is not so closely observed there as here. Unanimously replied that specialisation of products in special mills reduces cost. This is only feasible and practicable if there is some sort of understanding amongst the firms by which orders are apportioned and divided, thus allowing works to keep their mills employed on a specialised product.

(*b*) Continuous finishing mills are suitable and give cheap working costs; most suitable for billets from 2 in. to 3 in. square, and for wire rods; if plenty of orders, for small flats, small angles, and small rounds and squares. There may, perhaps, be less accurate rolling of some of the sections in continuous mills than is usual in this country, in which case a larger rolling margin would be necessary.

(*c*) Cogging mills, nil; plate mills, nil; rail mills, 0.63 per cent. Large finishing mills, from 7 per cent. to 15 per cent.; a fair average seems to be about 10 per cent. Small finishing mills, from 4 per cent. to 12 per cent.; a fair average of about 6 per cent. Roll-changing loss, of course, depends entirely on trade conditions—good trade, less roll-changing.

*Question No.* 2.

Please name any points you may have observed in the design and construction of foreign rolling mills which you consider material in increasing output.

SUMMARY OF REPLIES.

Eight replies in all have been received to this question, but practically all of them have gone beyond the scope of the question, in that not only do they deal with the design and construction of the mills, but introduce also into their replies the conditions under which the mills being compared are worked.

As this latter consideration is, in the opinion of the committee, more important than the question of design and construction, in so far as affecting the output is concerned, there is the difficulty at once presented of assessing the value to be attached to the questions of design and construction as compared with the value attaching to the different conditions of working.

It is worthy of note that in many of the replies received there is a marked consensus of opinion that mills which are being operated on specialised products, enabling long continuous runs on the same sections, minimising the delays caused by roll-changing, &c., are placed in a position of enormous advantage over similar mills which may be as good in regard to design and construction, but which have to operate on short runs, with frequent changing of rolls for small quantities. Taking, however, the questions of design and construction alone, the committee finds the further difficulty in the replies received that many of them compare the newest types of mills on the Continent and in America with the mills in their own works, many of which are now more or less out of date; and of course any such comparison is misleading.

The committee interpret the question as being put with a view to ascertain if the design and construction of modern mills in this country are outclassed by the designs of modern mills on the Continent and in America, but the parties replying to the question in many cases do not speak of the most modern mills in this country—indeed many of them have not seen these: but, taking the replies of those who are in a position, from their actual knowledge of the best practice in this country, as compared with foreign practice, to make a comparison, it is to be noted that three of these make the following remarks:—

(*a*) Replying to No. 2 question on broad lines, as far as regards detail, British practice is quite equal, and in many cases superior, to any Continental practice.

(*b*) Any mill combination of cogging, roughing and finishing does not give a greater output than a similar combination of our mills.

(*c*) There is practically no difference between modern British and foreign mills, either in design or method of operation.

Taking the point in regard to the conditions under which our mills work as compared with foreign mills, we have the following remarks in the replies received:—

(*d*) Speaks of the advantages enjoyed by foreign mills in "the limited range of sections rolled in any particular mill, and specialisation ensuring the proper division of work for different mills."

(*e*) As their rails and railway rolling-stock are standardised, they can secure large contracts for one or two sizes of rails in general use.

(*f*) Also the mills are generally specialised for their production, and they do not attempt to roll a large variety of sections in the same mill, as is the case in British works.

From a careful perusal of these answers the committee think that the fair conclusion to be drawn is that, comparing our best modern mills with foreign mills, we are not behind them in any respect as regards design and construction; and if the conditions in this country were such as would justify steel works owners in modernising their plants and bringing them up to date, there would be no disability in respect of the efficiency of British machinery, which, if operated under the more favourable conditions brought about by "specialisation," would be quite able to compete with the best of foreign plants, provided—but, of course, this is another matter—that the labour conditions in this country were equally favourable. There is no doubt at all that the conditions existing in America and in Germany, where the steel industry has been fostered by every means, present opportunities for engineers in those countries which have been denied us here, the British engineer never having the same chance of producing higher productive plants.

It is evident from the replies received that other conditions in the design and lay-out of foreign mills which generally affect the output are:—

Firstly: Better equipment for handling the material.

Secondly: Increased speed of rolling, and provision for this in ample power and strength and larger wearing surfaces.

Thirdly: Better lay-out and more space.

These provisions have not in the past been called for in this country because there has not been the demand for such large outputs, but we consider that it is most important to bear in mind and make provision for these in order to obtain the object in view of increasing production in the future.

*Question No.* 3.

Why is the three-high plate mill with continuously running flywheel and motor not in more general use in this country?

SUMMARY OF REPLIES.

Nine replies have been received to this question, and there is practical unanimity in the opinion that three-high mills have no advantages over the two-high reversing type, which is almost universal in this country. The main reasons are: That the two-high reversing mill, with roughing and finishing rolls, can give a uniformly better finish to plates, and roll to more accurate gauge thickness; and, as the requirements in respect to these two conditions are greatly stricter in this country than in foreign countries, the two-high mill is practically invariably preferred in this country.

The output of the modern two-high direct-driven mill is certainly not less than that of the three-high mill, and in many instances is distinctly greater. The wear and tear on the costly finishing rolls of the two-high mill is much less than in the three-high mill, as only the finishing part of the work is done in these, whereas in the three-high mill the whole work of roughing and finishing is done in one set of rolls. In the two-high mill the live roller gear is fixed on a level with the mill, and is less costly and much more reliable and easy of upkeep than the rising and falling tables required in the three-high mill, which frequently give much trouble and are costly in upkeep.

The two-high reversing mill has the further great advantage of starting slowly when the piece enters the rolls, and accelerating to the highest speed desired. This reduces initial shock to the lowest point, and yet enables a high average speed of delivery to be attained. On the other hand, in the three-high mill, which necessarily runs at a constant speed, the initial shock of the piece entering the rolls is very severe, and the speed of the mill has consequently to be kept down to a moderate point; so that, comparing the actual rolling speed of the two-high mill with the three-high, a considerably higher average rolling speed can be attained in the two-high mill, with a greatly lessened initial shock.

The sum of all these advantages is sufficient fully to explain why British practice is in favour of the two-high mill.

With regard to the claim that the continuous-running engine or motor associated with the three-high mill is of higher efficiency than the reversing engine or motor driving the two-high mill, modern British practice, in which the exhaust steam is used in low-pressure turbines for generating electric power, has largely met this disability, and put the reversing motor more on a par with the continuous-running motor, so that any difference now existing is of small importance compared with the other advantages.

*Question No.* 4.

What is your opinion as to the best types of manipulators for: (*a*) Cogging; (*b*) billeting; (*c*) finishing sections; (*d*) slabbing?

SUMMARY OF REPLIES.

A fair summary of the replies would be to say that for cogging down to small billets the consensus of opinion is that the manipulator must be of a type to seize, turn over, and hold the piece during its entrance into the rolls. This also applies with equal force in the case of billeting and finishing mills.

For slabbing work the holding up and guiding of the slab during the edging passes is an absolute necessity. It is well known that the best foreign cogging mills are equipped with a manipulator, consisting of long-power operated guides simultaneously operated at both sides of the rolls, the guides being equipped with self-contained tilting fingers. In the opinion of this committee, it is one of the best types of manipulator for the high production of blooms.

Some difference of opinion exists as to whether it is really necessary to turn over sections, and it appears that a similar type of manipulator of lighter and very much simplified construction without the tilting arrangement could be used to advantage on finishing mills.

*Question No.* 5.

What, under general conditions, do you consider the better method of driving, electrical or steam, the following classes of mills: (*a*) Reversing mills; cogging; finishing; plate mills. (*b*) Continuously-running bar and merchant mills?

SUMMARY OF REPLIES.

The replies received are, in the opinion of the committee, not sufficiently based on actual experience of electric driving. For continuously running mills they are unanimously in favour of electricity, providing the cost of power is not prohibitive. For reversing mills, cogging, finishing and plate mills the majority are in favour of electric driving, providing the cost of current is low, but there is a substantial minority who still advocate steam driving.

Advantages of electrical drive: Uniform turning movement; cleanliness; accurate data as to power consumed; generating plant all in one station; perfect speed control and smooth running; higher efficiency.

Objection: Great initial cost of plant.

Some interesting diagrams giving the number of units per ton are furnished by two British firms, and several load diagrams, as well as output and power consumed in United States mills, have been furnished. The committee suggest that these may be lodged in the library of the Institute, omitting the names of the firms, if the council decide to do so.

*Question No.* 6.

Is output materially influenced by differences in conditions of labour abroad and in this country, giving any instances and particulars?

SUMMARY OF REPLIES.

It is generally admitted that longer hours worked in the United States of America and on the Continent tend to reduce cost, but main causes of reduced cost are: (*a*) Greater effort on the part of men; (*b*) labour-saving devices; (*c*) confident expenditure of capital in order to bring plant up to date and secure maximum output in given time, also to eliminate all waste; (*d*) military training on the Continent makes the men there more obedient and methodical in their ways than in England; (*e*) absence of restriction of output.

*Question No.* 7.

What is the maximum cost per unit of current at which installation of electric drive is warranted for reversing, cogging and finishing mills? Please give any information you can as to the number of units consumed per ton of material, giving sizes and elongation.

SUMMARY OF REPLIES.

The price per unit of current stated in the replies varies greatly. It is generally considered that with coal at 10*s.* per ton, if current can be got at 0.35*d.*, then electric driving is undoubtedly a favourable proposition, but anything above this figure would require to be carefully investigated. A few records are given of the number of units consumed per ton of steel rolled, but they naturally vary with the class of steel rolled and size of bar, and cannot therefore be expressed in general terms.

*Question No.* 8.

Can you give any figures as regards weight of steam used in high-pressure or compound engines per ton of finished product in stated elongation?

SUMMARY OF REPLIES.

There appears to be a lack of sufficient information available to enable any definite statement to be made. The conditions which govern the power required for rolling are principally and in order of importance:—(1) Temperature of steel being rolled; (2) speed at which the piece is rolled; (3) quality of steel; (4) drafting of the roll passes; (5) design and construction of the rolling mill.

*Question No.* 9.

What is the present position of the large gas engine for generation of power or for blowing? State your experience of such engines, saying under what conditions of gas and steam supply you would still install them.

SUMMARY OF REPLIES.

The replies to this question indicate that the gas engine is much more economical in fuel than the steam-engine or turbine. On the other hand, the initial cost of gas engines is usually greater. The gas engine is not so reliable, the cost of attendance and upkeep is greater, and the stoppages for cleaning and repairs are more frequent. The balance of opinion is in favour of the gas engine only when the highest quality of engine is installed and worked with well-cleaned gas and within its rated load capacity, and when the gas saved by the superior economy of the gas engine can be fully utilised for other purposes. In the case of blowing engines it is necessary to install steam sets as stand-by.

*Question No.* 10.

Is turbo machinery displacing the gas engine for either of those purposes?

SUMMARY OF REPLIES.

Answers to this question have been received from nine different firms, and, although certain opinions are diametrically opposed, the balance appears to be in favour of the gas engine.

The only direct evidence of turbo machinery displacing the gas engine occurs in one answer, which mentions two instances in this country where gas engines were installed some years ago for blowing purposes, and at the present time are being replaced by turbine blowers. Another answer mentions one case at least within his personal knowledge, others from reports. The general impression, however, appears to be that whilst turbo machinery is decidedly less expensive, both as regards capital cost and maintenance, the relatively high thermal efficiency of the gas engine more than compensates for this.

There is no convincing evidence that gas engines are superior to turbo blowers, when all considerations in regard to first cost, reliability in working, cheapness of upkeep, and simplicity of construction are fully taken into account; each installation must necessarily be

determined by local conditions, that may cause the balance in each individual case to be on the one side or the other.

Certain replies point out that the whole question concerns the most efficient use of available heat, and, although not mentioned in any of the answers, it is possible that consideration of an installation of steam turbines and full use of blast-furnace gases, and waste-heat boilers applied to the Siemens furnaces, might modify some of the views expressed.

*Question No.* 11.

Give what figures you can regarding the cost of generation of current by blast-furnace and coke-oven gas, including all costs, and stating the method of generation.

SUMMARY OF REPLIES.

Five answers have been received to the question. Only one of these, however, gives any information regarding the use of coke-oven gas for this purpose. Unfortunately some of these replies do not give very complete information, and it is scarcely possible to summarise results. The figures given are tabulated below :—

| Cost per Unit. Mixed Pressure Turbo. | Cost per Unit. High - Pressure Turbo. | Cost per Unit. Blast - Furnace Gas. | Cost per Unit. Coke-Oven Gas. | Cost per Unit. Type of Generators not stated. | Units Generated. | Remarks. |
|---|---|---|---|---|---|---|
| / — | — | 0.458 | — | — | 4,800,000 | Includes :— |
| 0.339 | — | — | — | — | 2,400,000 | Wages. |
| | | | | | | Stores and renewals. |
| | | | | | | Gas and/or steam. |
| | | | | | | Electricity used. |
| | | | | | | Depreciation. |
| — | — | — | — | 0.15 | — | Includes all charges. |
| — | 0.17 | — | — | — | — | Turbines 2,000-kw. capacity. |
| | | | | | | Steam raised in water-tube boilers using uncleaned blast-furnace gas. |
| | | | | | | Cost of gas not included. |
| — | — | — | 0.4 | — | — | 500-kw. set stated as much overrated. |
| | | | | | | Includes 20 per cent. depreciation, and gas, oil and repairs. |
| 0.28 | — | — | — | — | — | No details of costs stated. |
| — | — | — | — | 0.17 | — | Cost of gas cleaning 0.1. |
| | | | | | | Cost in power-house 0.07. |
| — | 0.16 | — | — | — | 30,000,000 | This is an assumed installation of two 5,000-kw. turbo alternators generating current at 5,000 volts. |
| | | | | | | Steam generated in gas-fired water-tube boilers at a pressure of 250 lb. per square inch and superheated to 640 deg. F. |
| | | | | | | Gas from Scottish type blast - furnaces — average calorific value 125 British thermal units per cubic foot. |
| | | | | | | Charged to power-house at 0.3 of a penny per 1,000 cub. ft. |
| | | | | | | All generation and transmission costs included. |

GENERAL REMARKS.

The opinion is expressed that if the steel trade of Britain is to hold its own in open competition with the other steel-producing countries of the world, it will be necessary, amongst other changes, to have a Central Board to which all orders will go, and from whence the work will be allocated to the different works according to their ability to do it. This would save the enormous amount of capital at present locked up in stocks of rolls. Many works have rolls for practically all the British standard sections, and change the rolls as required to suit orders. If, on the other hand, the orders were sent from a Central Board, mills could be kept on the work allocated to them for long periods, thus reducing the amount of roll-changing and also the cost of production. It would also enable works to roll only such material for which their mills and plant are best adapted.

It is clear to the committee that the one outstanding feature which has been revealed by their work, so far as it has gone, has been the eliciting of the almost unanimous opinion that if the steel industry in this country is going to maintain its position, it must be by some great broadening of our commercial organisations that would lead to economies far and away outweighing any other element in the situation, and long ago realised and adopted by our foreign competitors.

BETHLEHEM COMPANY'S STEEL PRODUCTION.—According to *The Iron Age*, the Bethlehem Steel Company, Bethlehem, Pa., commenced the operation of a new 200-ton, open-hearth, steel tilting furnace at its local works on August 17. The new furnace will increase the output of the works from 50,000 tons to 60,000 tons a month. It had been in construction for a year.

# NEW EXPERIMENTS ON SHOCK TESTS AND ON THE DETERMINATION OF RESILIENCE.*

By GEORGES CHARPY and ANDRÉ CORNU-THENARD (Paris).

INTRODUCTION.

As is well known, the International Association for the Testing of Materials appointed, on the occasion of the Copenhagen Congress and after discussing a report presented by one of the authors,† a special committee (Committee 26) to define clearly the method to be adopted in carrying out resilience tests and also to investigate the connection which exists between the results of these tests and the behaviour of metallic parts in practice.

The researches which form the object of the present memoir relate to only the first half of the question, which it is necessary to elucidate before the second half can be advantageously attempted. Carried out in 1913 and 1914, they were intended to serve as a basis for the consideration of Committee 26, in order to frame suggestions for submission to the Congress which was to have been held in Petrograd in 1915. In order to increase, as far as possible, their practical value we have taken resilience itself and justifies a close study of the whole question. To demonstrate the accuracy of this point of view it would be necessary to succeed in preparing metals certain to give, under ascertained conditions, results comprised within two well-defined and not widely separated limits. This is what the authors have been able to do, as will be seen later, and it is this that has permitted of their obtaining results of which the regularity, clearly demonstrated on considering the average divergence calculated over the whole of the experiments made, is comparable with that of no other mechanical test whatever.

Secondly, it has appeared to the authors that once a question had lent itself to controversy and had been made the subject of conflicting observations on behalf of different investigators, a fresh series of measurements would always be insufficient to satisfy everyone beyond possibility of doubt. The authors conceived, therefore, that it would be an advantage to submit their own tests to a certain number of competent persons for checking, and they have, with this object, presented the members of Committee 26 with a programme of experiments intended to throw light on the principal points of the question in dispute ; and after it had thus been discussed

| Series of Bars. | Shock Tests. Individual Resiliences. | $R_m$. | $\epsilon_m$. | $E_m$. | Maximum Divergence. | Hardness Tests. Individual Hardness Nos. | $D_m$. | $\epsilon_m$. | $E_m$. | Maximum Divergence. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | per cent. | | | | | per cent. | |
| A : 1 | I. 21.21 | 16.57 | ±6.3 | 38.0 | 27.31 to 4.18 | 189.0 | 187.4 | ±2.6 | 1.3 | 193.0 to 183.5 |
| | II. 15.16 | | | | | 185.5 | | | | |
| | III. 14.62 | | | | | 193.0 | | | | |
| | IV. 10.19 | | | | | 188.5 | | | | |
| | V. 4.18 | | | | | 185.5 | | | | |
| | VI. 27.31 | | | | | 183.5 | | | | |
| | VII. 23.31 | | | | | 184.0 | | | | |
| A : 2 | I. 25.48 | 15.27 | ±7.9 | 52.1 | 25.48 to 2.69 | 190.0 | 188.8 | ±3.9 | 2.0 | 199.5 to 180.0 |
| | II. 12.48 | | | | | 191.0 | | | | |
| | III. 13.28 | | | | | 199.5 | | | | |
| | IV. 4.78 | | | | | 186.0 | | | | |
| | V. 2.69 | | | | | 188.0 | | | | |
| | VI. 22.72 | | | | | 180.0 | | | | |
| | VII. 25.48 | | | | | 187.5 | | | | |

| Series of Bars. | Shock Tests. Individual Resiliences. | $R_m$. | $\epsilon_m$. | $E_m$. | Maximum Divergence. | Hardness Tests. Individual Hardness Nos. | $D_m$. | $\epsilon_m$. | $E_m$. | Maximum Divergence. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | per cent. | | | | | per cent. | |
| A : 5 | I. 20.51 | 19.05 | ±4.0 | 20.9 | 27.60 to 10.13 | 175.0 | 177.0 | ±2.0 | 1.1 | 182.5 to 174.5 |
| | II. 23.04 | | | | | 174.5 | | | | |
| | III. 10.13 | | | | | 182.5 | | | | |
| | IV. 27.60 | | | | | 178.5 | | | | |
| | V. 15.66 | | | | | 177.0 | | | | |
| | VI. 18.35 | | | | | 174.5 | | | | |
| | VII. 18.05 | | | | | 177.0 | | | | |
| A : 7 | I. 25.73 | 21.54 | ±2.77 | 12.8 | 25.73 to 14.36 | 173.5 | 177.0 | ±2.3 | 1.2 | 180.5 to 173.5 |
| | II. 25.73 | | | | | 178.5 | | | | |
| | III. 14.36 | | | | | 180.0 | | | | |
| | IV. 22.32 | | | | | 174.5 | | | | |
| | V. 21.99 | | | | | 180.5 | | | | |
| | VI. 21.65 | | | | | 176.0 | | | | |
| | VII. 19.03 | | | | | 176.0 | | | | |
| A : 8 | I. 22.50 | 20.17 | ±1.69 | 8.3 | 23.57 to 16.67 | 169.0 | 177.6 | ±3.3 | 1.8 | 182.0 to 169·0 |
| | II. 20.39 | | | | | 179.0 | | | | |
| | III. 16.67 | | | | | 182.0 | | | | |
| | IV. 23.57 | | | | | 179.5 | | | | |
| | V. 18.00 | | | | | 181.5 | | | | |
| | VI. 20.04 | | | | | 175.0 | | | | |
| | VII. 20.04 | | | | | 177.5 | | | | |

certain precautions on which we deem it advisable to lay emphasis, seeing that in investigations relating to the question in hand it seems to the authors that the influence of the degree of accuracy has been a little underestimated. Most investigators who have published researches on bend tests of notched bars appear to have renounced all attempts to obtain a series of results devoid of accidental differences. Some attribute such irregularities to the mode of testing itself ; others challenge the homogeneity of the metal under investigation.‡

It is necessary to choose between these two opinions; the first would lead, in the authors' opinion, to the complete abandonment of this method of testing regarded as a means of ascertaining the quality of metals, or, what is still more important, of deciding the treatment prior to use. In regard to the second opinion, it is necessary, on the contrary, to recognise that the bend test on notched bars possesses a degree of extreme sensitiveness which serves to reveal certain physical states not revealed by any other of the usual tests, and of which the influence, from a practical point of view, should not be neglected. This sensitiveness confers a special interest on and defined, they invited all the members of this committee to be present during the carrying out of a complete series of determinations made on the material at the laboratory of the Conservatoire National des Arts et Métiers by the staff of that institution. Their results have thus received, in some sort, official sanction, evidenced by the report of the Conservatoire, to which may be added the weight of the authority of the personages, French and foreign, who responded to the authors' invitation. These comprised :—

Mr. Keelhoff, professor at the University of Ghent.

Mr. Camerman, chief of the Testing Department of the Belgian State Railways.

Dr. Stanton, National Physical Laboratory.

Mr. Mesnager, director of the Testing Laboratory of the French Government Department *des Ponts-et-Chaussées*.

Mr. Guillery, director of the firm of Messrs. Malicet and Blin.

Mr. Belanger, engineer-in-chief of the Paris, Lyons and Mediterranean Railway.

Mr. Cellerier, director of the Laboratory of the Conservatoire des Arts et Métiers.

Mr. Sabatier, chief of the Metallurgical Section of the Conservatoire.

The report relating to the experiments carried out during the course of this session is given at the end of the present paper. It will be seen to confirm in the most complete manner possible the authors' own determinations.

The authors would like, at this point, to emphasise the advantages which arise, from the material point of view, from generalisations conducted in such a manner. They believe that official laboratories and institutions might, with the happiest results, address a part of their activities to the verification of results, on the invitation of those interested, and assist in helping to decide between investigators who had arrived at divergent conclusions.

* Paper read before the Iron and Steel Institute, September 21, 1917.

† Report to the Copenhagen Congress, 1909, by G. Charpy ; see also the Report to the New York Congress, 1912, by the same author.

‡ The latter view is expressed with special clearness in a report presented to the New York Congress by Mr. Belanger, the engineer-in-chief of the Paris, Lyons and Mediterranean Railway, in which he states : "Even amongst steels reputed to be the most homogeneous (crucible and electric steels) the resiliences vary from unity to double, a few centimetres only apart ; at a distance of a metre they vary sometimes from unity to fourfold" (Report by Mr. Belanger to New York Congress (IV. 5), "Resilience," p. 10).

In short, they might fix definite starting-points for new investigations. The Proceedings of such institutions would thus become an epitome of industrial scientific documents properly authenticated and capable of rendering the very greatest service to investigators.

The method of research having thus been clearly defined, the details of the investigations now presented by the authors will consist of three principal portions :—

1. Preliminary definitions (definition of the regularity of the experiments and the determination of the degree of comparability of the shock test appliances employed).
2. Preparation of series of bars possessing equal resilience.
3. Determination of the influence of the different variables involved in the shock test.

## I. Preliminary Determinations.

1. *Numerical Definition of the Regularity of the Experiments.*—It was indispensable to establish a numerical definition of the regularity of the experiments, as much for the purpose of guiding the authors in their research on the constitution of series of bars possessing similar resilience as to enable them to ascertain, without ambiguity, the influence of the various factors intervening in the shock test.

The considerations which follow apply equally to every type of test, particularly to shock bending tests, which are that the small local irregularities which may subsist from one point of the metal to another do not interfere to any appreciable extent. The authors do not lay particular stress on this portion of their researches, which have been described in the *Revue de Métallurgie*,* and will confine themselves to recording certain general results to give an idea, on the one hand, of the regularity of the results which can be obtained with carefully manipulated shock-testing apparatus, and, on the other hand, of the application of calibration methods to testing appliances capable of undergoing this process of investigation.

Each series of experiments, summed up in a single line of the table given below, comprises results from five bars. Besides these, two series of test-pieces were tested on each of two drop-pendulum machines which the authors had available, thus bringing into play different conditions of bending.

The regularity these results present was not attained without difficulty. The authors found in the course of this investigation the importance, from the point of view of the accuracy of the experiments, of an accurate definition of the parts in contact with the bars (the edge of the knife, the supports, &c.) and of the accurate machining of these elements. The authors have, naturally, taken into account these considerations in the ultimate tests on notched bars.

machine brought out identical results. It is possible therefore to proceed still further and to draw the conclusion that the mode of operation above described allows the ascertainment—(1) of the relative regularity of the testing appliances; and (2) of the agreement or the discrepancies which exist in regard to the graduations of two such appliances.

## II. Preparation of Series of Bars having Equal Resilience.

### A. *Preliminary Tests.*

1. *Taking Metal Samples.*—The authors have sought to avoid, as completely as possible, the occurrence of chemical or physical heterogeneity in the metal, by employing the process already described by one of them and removing a relatively small fragment of metal from the sound portion of a very large ingot. In regard to a steel of the semi-hard type (metal A) which served for the greater part of the authors' preliminary investigations, they were able to carry matters to an extreme point. They had, as a matter of fact, an ingot of 45 tons weight at their disposal, from which they removed portions weighing 25 kg., each of which weighed therefore but

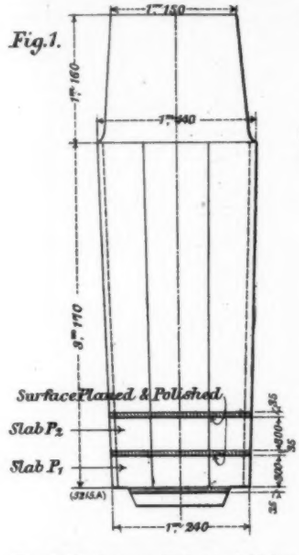



FIG. 1. Section across the ingot of 45 tons weight from which was taken the semi-hard steel which served for the experiments.
*Slab* $P_2$.—Portion of the ingot from which were cut the blocks which, on forging, supplied the bars. For the distribution of these blocks see Fig. 3. The upper surface was examined from the point of view of ascertaining the homogeneity of the structure.
*Slab* $P_1$.—Portion of the ingot forming the lower crop. The upper surface was similarly examined for homogeneity.

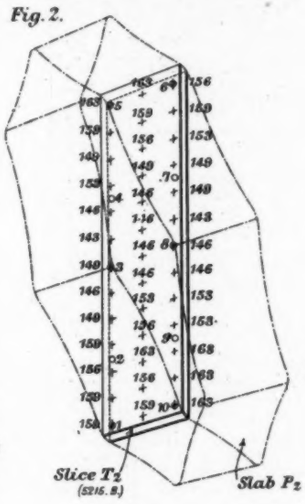



FIG. 2. Perspective view of slice II, which was cut in the depth of slab $P_2$, along a diametrical section. On this slab are shown (1) the points (+) where the ball impressions were made, with the corresponding Brinell numbers, and (2) the points (o) from which drillings were removed for the chemical analyses.

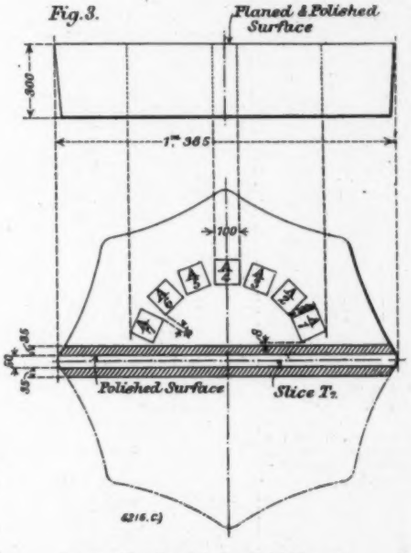



FIG. 3. Elevation and plan of slab $P_2$. On the plan are shown the blocks A which were cut from the slab at equal distances from the centre and the sides of the ingot so as to utilise only the soundest portion of the metal. Each of these blocks weighed 25 kilograms, or $\frac{1}{1800}$ part of the total metallic mass (45 tons).

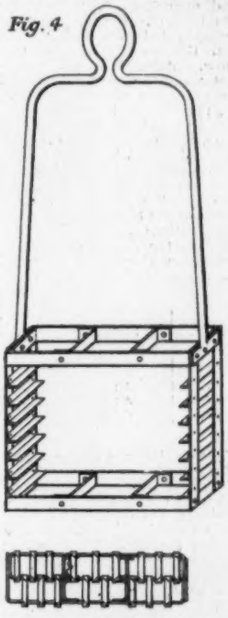



FIG. 4. View, in perspective, of one of the types of frames employed in the heat treatment of the test bars and plan of one of the drawers in the frame. The bars are fixed by means of wire, at equal distances from one another, in the drawers; the drawers, thus loaded, are introduced into the frame, and the arrangement is then plunged in succession into the different metallic baths for reheating, and, lastly, into the quenching bath.

dealt with later, and to the hardness tests, which were often carried out parallel with the resilience tests themselves. The shock test is here only taken as an example to render the explanation the easier.

For instance, if an experiment be made on $n$ bars, all broken under the same conditions, we obtain the values $n$ of the resilience R, of which the arithmetical mean gives the average resilience $R_m$. The accuracy of the experiment is determined by the following considerations :—

The average divergence $\epsilon_m$; the arithmetical mean of the absolute values of the differences $(R - R_m)$ between the individual resiliences and the average resilience, and

The maximum divergence; the difference between the extreme individual resiliences.

The average relative resiliences $E_m$ may also be considered by comparing the average divergence $\epsilon_m$ with the average resilience $E_m$.

It may be said, therefore, that the regularity of a series of determinations will be satisfactory when the value of the average divergence, or of the relative average divergence, is below some given and predetermined number. In practice it suffices if the average relative divergence remains below 5 per cent.

2. *Determination of the Degree of Sensitiveness and of the Comparability of the Apparatus Employed.*—Before proceeding any further it was necessary to establish clearly that the irregularities, of which mention has been made above, were not due to the testing apparatus, but actually to the material to be tested; in other words, it was necessary to be certain that an apparatus properly constructed on satisfactory principles would always yield results mutually comparable, and likewise comparable with those given by every other apparatus fulfilling the same conditions as to design and principles.

With this object the authors have employed unnotched bars in such a way as to limit the deformation to a well-defined bend without carrying it as far as fracture, so

| Dimensions of the Bars. | Nature of the Metal. | Average Energy absorbed in Bending. | Average Divergence. | Relative Average Divergence. | Extreme Individual Results. |
|---|---|---|---|---|---|
| | | | *30-Kilogram Drop-Pendulum Machine.* | | |
| | | Kg. | Kg. | p.c. | Kgm. |
| 53.3×10×5 | Gun steel | 9.954 | ±0.093 | 0.9 | 9.720 to 10.110 |
| 53.3×10×5 | ,, | 15.446 | ±0.216 | 1.4 | 15.040 to 15.720 |
| | | | *300-Kilogram Drop-Pendulum Machine.* | | |
| 200×30×13 | Mild steel (boiler plate) | 166.508 | ±1.678 | 1.0 | 163.710 to 169.300 |
| 160×30×15 | Gun steel | 255.807 | ±1.144 | 0.4 | 254.570 to 256.660 |

An examination of this table shows :—

1. That unnotched bars, prepared with certain precautions, give, when made with the same apparatus and under similar conditions, results which are practically identical, and

2. That the irregularities displayed by different notched bars, when submitted to the shock test, are attributable, not to the testing machine, but to the material itself under test.

Similar experiments carried out on a vertical drop-test

* "Note on a System of Calibrating Apparatus for the Shock-testing of Metals," by G. Charpy and A. Cornu-Thenard: *Revue de Métallurgie*, 1913, p. 1233.

$\frac{1}{1800}$ of the original mass of metal. The authors will describe later, and in detail, the check tests they made in this particular instance before putting into practical use the portion of the ingot reserved for this investigation.

Two slabs, $P_1$ and $P_2$, each 300 mm. in depth, were taken from the bottom of the ingot (Fig. 1); the upper sections of each of these slabs were etched with iodine and then with sulphuric acid without any heterogeneity revealing itself on macrographic examination.

The slab $P_2$ was sawn into two equal portions so as to take between them the vertical slice $T_2$ of 50 mm. in thickness, in order to study the metal from the mechanical and chemical points of view, in the depth of this portion of the ingot. With this object this slab, after having been subjected to annealing in order to remove the stresses which might have been occasioned during the pouring, was submitted to ball hardness tests over its entire surface. These tests, distributed as shown in Fig. 2, showed an average hardness of 153.4 ± 5.6, that is to say an average relative divergence of only 3.6 per cent. There were then a number of drillings made at various points in the section, for the purpose of the chemical analysis, which yielded very concordant results, which are summarised in the table given on the next page. The metal appearing to possess a satisfactory degree of homogeneity, parallelopiped strips of 100 mm. by 100 mm. by 300 mm., from the portion concentric with the axis and from the median part of the ingot, were cut in the manner shown in Fig. 3.

2. *Influence of the Superficial Layers.*—Each strip A, rolled into a square bar 34 mm. by 34 mm., furnished one series of test-bars; each of these was marked with the letter designating the metal, the number of the original strip, and the number of the test-bar taken from that strip. Thus the eighth test-bar taken from the fifth strip of the metal A has been distinguished by the marking A, V, 8. Each series of determinations comprises all the test-bars bearing the same final number

forder of the bar in relation to the strip); thus the experiments shown under the designation A, 0, used up all the sixth bars of each of the even strips of A.

*Chemical Composition. The drillings were removed from the points marked* o *in the figure* (2).

| No. | Carbon. | Silicon. | Manganese. | Phosphorus. | Sulphur. |
|---|---|---|---|---|---|
| 1 | 0.33–0.34 | 0.28 | 0.77 | 0.022 | 0.014 |
| 2 | 0.33–0.32 | 0.27 | 0.75 | 0.020 | 0.014 |
| 3 | 0.33–0.29 | 0.28 | 0.74 | 0.017 | 0.010 |
| 4 | 0.33–0.28 | 0.28 | 0.74 | 0.018 | 0.010 |
| 5 | 0.37–0.38 | 0.27 | 0.76 | 0.022 | 0.014 |
| 6 | 0.30–0.32 | 0.28 | 0.77 | 0.022 | 0.014 |
| 7 | 0.27–0.28 | 0.26 | 0.74 | 0.019 | 0.010 |
| 8 | 0.26–0.32 | 0.26 | 0.72 | 0.017 | 0.010 |
| 9 | 0.30–0.34 | 0.28 | 0.75 | 0.019 | 0.014 |
| 10 | 0.25–0.29 | 0.27 | 0.76 | 0.024 | 0.012 |

The test-bars were then annealed to remove the stresses due to rolling, machined to the dimensions 30.5 by 30.5, and submitted to heat treatment, that is quenching and annealing. The heating was effected by means of a little gas furnace using common gas, fifty test-bars being heated at a time and the temperatures noted by a Le Chatelier pyrometer, at different points within the mass. After finishing, punching and notching the test-pieces the results recorded in the table on page 346 were obtained on shock-testing.

In spite of all the precautions taken the authors again found all the irregularities so often noticed in resilience tests, while finding the hardness practically constant in the different bars.

The authors felt led, by certain observations, to ask themselves whether, during the course of the treatments to which the metal has been subjected, the superficial layers of the test-pieces may not have undergone certain modifications capable of influencing, in some appreciable manner, the results of the shock test: to verify this conclusion they had recourse to planing the lateral faces of the following bars, so that:

| Bars. | Series. | Depth Planed off. | Section. |
|---|---|---|---|
| | | mm. | |
| 7 | A : 5 | 1 | 15 × 28 |
| 7 | A : 7 | 2 | 15 × 26 |
| 7 | A : 8 | 3 | 15 × 24 |

The results on shock testing are tabulated on page 346.

The experiments appear conclusive: simply planing the lateral faces has made the relative average divergence fall from about 40 per cent. to 8 per cent., while the hardness tests applied to the surface reveal, on the contrary, no similar variation and remain perfectly regular. One of the first conditions to be fulfilled, in securing homogeneous results in a series of shock tests, is therefore to eliminate the superficial layers of the bars after treatment.

3. *Influence of the Temperature of Rolling.*—On the other hand some experiments carried out on another steel lead the authors to believe that the temperature of rolling may influence resilience. In order to ascertain the extent of this influence on the metal A, they had two blocks rolled from their 45-ton ingot, one at about 1200 deg. C., the other at about 800 deg. C. The bars thus obtained were annealed at about 900 deg. C. and cooled in the furnace. On removal the bars were quenched and annealed, then machined to the dimensions of 30 by 30, punched and notched. The results of this experiment were as follow:—

*Metal A.*

| No. of Bars. | $R_m$. | $\epsilon_m$. | $E_m$. | Maximum Divergence. |
|---|---|---|---|---|
| 5 | 16.30 ±1.22 | | 7.5 per cent. | 18.57 to 13.81 |

The results shown in the foregoing table do not, even yet, attain to the degree of uniformity sought by the authors. It appeared to them at this juncture that the carrying out of the heat treatments might leave something to be desired, and they therefore decided to effect the heating by treating all the bars of a single series simultaneously, in a bath of lead. The mode adopted was as follows:—

After the original blocks had been rolled into bars and these bars annealed, the test-bars, in portions measuring 35 mm. by 35 mm. by 160 mm., were arranged in sets of 14 or 28 (in the case of half-bars), according to circumstances, in the frames shown in Fig. 4. These frames were then immersed, in succession, in three baths of lead. The first, in which immersion lasted twenty minutes, raised the metal to about 400 deg.; the second, in which the immersion lasted thirty minutes, brought the metal to within a few degrees below the desired temperature, so that the temperature of the third, in which immersion lasted thirty minutes, was not appreciably altered (10 deg. C. at a maximum) by the introduction of the charge, and this temperature was therefore capable of being maintained uniform and ascertained with considerable accuracy. Each quenching, per frame, was carried out by immersing all the bars simultaneously in water or in oil, according to the nature of the composition of the metal; cooling, after annealing, was effected in ordinary open air.

The bars thus treated were machined to 30 by 30 by 160; punched, gauged and notched.

The experiments carried out under these conditions on the metal A display superior uniformity to those previously obtained. The first test carried out under these conditions gave the following result:—

*Metal A.*

| No. of the Bars. | $R_m$. | $\epsilon_m$. | $E_m$. | Maximum Divergence. |
|---|---|---|---|---|
| 5 | 24.11 | ±0.88 | 3.6 per cent. | 25.48 to 23.01 |

Experiments carried out similarly on bars measuring 10 by 10 by 53.3 led to the same conclusions. They have not been hitherto mentioned in order not to confuse the subject.

B. *Determinate Experiments.*

1. *Description of Results.*—It remained to confirm the results obtained by checking their accuracy over a certain range in the scale of resiliences.

For this purpose the authors took blocks of a metal J, which was semi-hard and contained nickel* (weight of original ingot = 25 tons), and of a metal P, which was hard and contained chromium-nickel (weight of original ingot 2.5 tons), which were both made to undergo the series of operations described in the previous sections. Each series comprised five bars, and the results obtained are set out in the table in the next column. This table also shows, for the purpose of comparison, the uniformity obtained with commercial copper (quenched from 800 deg. C.).

2. *Conclusions.*—The results given in this table show, therefore, that it is possible to obtain, in the course of experiments in resilience tests carried out on bars of steel of different natures, or on copper, a degree of uniformity analogous to that obtained by means of tensile or of hardness tests.

On the other hand, the course of the experiments previously detailed clearly invalidate the opinion of certain authors, adherents of the employment of a V-shaped notch, according to whom the sensitiveness of the shock test is appreciably diminished by the use of the cylindrical notch known as the Copenhagen notch. The authors find, indeed, that given the same metal with the same form of bars notched cylindrically, that the test numbers are grouped in perfectly concordant groups when the precautions are properly taken, and into discordant numbers in the opposite case. The degree of uniformity attained is not therefore due to defective sensitiveness, for this, in the two alternatives, remains the same, but rather to an improvement in the method of preparing the material to be tested.

These preliminary observations being made, the authors are now able, in the sequel, to sum up briefly the whole of the precautions which they were led to take to form the series of uniform bars.

1. It is obviously necessary to select a sample of homogeneous metal by removing it from the soundest portion of the ingot; the uniformity exhibited by the steel P, derived from an ingot of about 2.5 tons, shows, however, that it is useless to require abnormal masses of metal.

2. It is necessary to eliminate the outer layers of the test-bars after heat treatment. The surface perturbations to which the authors will presently have occasion to revert, and which are here regarded solely from the point of view of the choice of conditions in the materia] to be tested, are more or less marked according to the nature of the metal. The authors have adopted, as a general rule, bars of 35 mm. by 35 mm., as a starting point, for the preparation of bars measuring 30 mm. by 30 mm., and of bars of 15 mm. by 15 mm. for the preparation of test-pieces measuring 10 mm. by 10 mm.

| Series. | Types of Bars (Copenhagen Notch). | Individual Resiliences. | $R_m$. | $\epsilon_m$. | $E_m$. | Maximum Divergence. |
|---|---|---|---|---|---|---|
| Metal A— | mm. | | | | per cent. | |
| I. | 30×30×160 | 23.01 | 24.11 | ±0.88 | 3.6 | 25.48 to 23.01 |
| II. | | 24.85 | | | | |
| III. | | 24.23 | | | | |
| IV. | | 25.48 | | | | |
| V. | | 23.01 | | | | |
| 1 | 10×10×53.3 | 16.18 | 16.42 | ±0.20 | 1.2 | 16.92 to 16.18 |
| 2 | | 16.43 | | | | |
| 3 | | 16.92 | | | | |
| 4 | | 16.43 | | | | |
| 5 | | 16.18 | | | | |
| Metal J— | | | | | | |
| I. | 30×30×160 | 18.10 | 17.96 | ±0.13 | 0.7 | 18.1 to 17.81 |
| II. | | 17.81 | | | | |
| III. | | 18.10 | | | | |
| IV. | | 18.10 | | | | |
| V. | | 17.81 | | | | |
| 1 | 10×10×53.3 | 12.16 | 12.48 | ±0.34 | 2.7 | 13.07 to 11.93 |
| 2 | | 12.62 | | | | |
| 3 | | 12.62 | | | | |
| 4 | | 13.07 | | | | |
| 5 | | 11.93 | | | | |
| Metal P— | | | | | | |
| I. | 30×30×160 | 10.08 | 9.98 | ±0.15 | 1.5 | 10.08 to 9.59 |
| II. | | 9.59 | | | | |
| III. | | 10.08 | | | | |
| IV. | | 10.08 | | | | |
| V. | | 10.08 | | | | |
| 1 | 10×10×53.3 | 5.13 | 4.76 | ±0.15 | 3.3 | 5.13 to 4.63 |
| 2 | | 4.63 | | | | |
| 3 | | 4.63 | | | | |
| 4 | | 4.79 | | | | |
| 5 | | 4.63 | | | | |
| Copper— | | | | | | |
| I. | 30×30×160 | 12.35 | 12.14 | ±0.27 | 2.2 | 12.61 to 11.83 |
| II. | | 12.09 | | | | |
| III. | | 11.83 | | | | |
| IV. | | 12.61 | | | | |
| V. | | 11.83 | | | | |
| 1 | 10×10×53.3 | 4.76 | 4.95 | ±0.23 | 4.6 | 5.41 to 4.76 |
| 2 | | 4.76 | | | | |
| 3 | | 5.08 | | | | |
| 4 | | 5.41 | | | | |
| 5 | | 4.76 | | | | |

3. The temperatures of rolling and forging should, for any one series, be as similar as possible. In particular, it is desirable, in any one bar, to make as large a crop as possible at each end in order to eliminate the portions which may have undergone abnormal cooling in the course of hot-working.

4. It is absolutely necessary to carry out the heat treatments under the most uniform and accurate conditions attainable.

*(To be continued.)*

| Steel. | Temperature of Rolling. | No. of Bars. | Resilience Tests. $R_m$. | Resilience Tests. $\epsilon_m$. | Resilience Tests. $E_m$. | Resilience Tests. Maximum Divergence. | Hardness Tests. $D_m$. | Hardness Tests. $\epsilon_m$. | Hardness Tests. $E_m$. | Hardness Tests. Maximum Divergence. |
|---|---|---|---|---|---|---|---|---|---|---|
| | deg. | | | | per cent. | | | | per cent. | |
| A | 800 | 5 | 29.05 | ±5.97 | 20.5 | 44.00 to 22.71 | 173.4 | ±3.32 | 1.9 | 178.0 to 166.2 |
| A | 1,200 | 5 | 22.23 | ±1.17 | 5.2 | 24.23 to 20.02 | 170.1 | ±1.72 | 1.0 | 172.5 to 167.5 |

The authors had assumed, up to the present, that the more or less pronounced interstraining produced during the course of the rolling or of the forging would be completely removed by a suitably selected further heat treatment. The foregoing table brings out, on the contrary, the fact that if this be really so in regard to the ball-tests, it no longer holds true as regards the resilience tests. On the other hand, it had been found that not even micrography could reveal, after the treatment, any difference between the structure of the cold-rolled metal and that of the hot-rolled metal.

4. *Influence of Inaccuracy in the Heat Treatment.*—These first results having been secured, the authors sought to eliminate the influence of the surface layers, and of the rolling temperature, by operating as follows:—

A new block of metal A was transformed, by rolling, into a bar of 35 sq. mm.; this, after undergoing a first annealing, was cut up into portions capable of being rolled into bars of 160 mm. in length. These portions were themselves subjected to heat treatment (quenching and annealing) in the conditions described above and then trimmed to the dimensions of 30 by 30, punched, notched and tested. The series was thus composed of five consecutive lengths cut from the same bar. The results of a number of determinations were:—

* In order to obtain regularly graduated resiliences with the metals at the authors' disposal they were obliged to use a few special steels.

ELECTRIC HEADLIGHTS ON BALTIMORE AND OHIO RAILROAD.—The Baltimore and Ohio Railroad, says *The Electrical Review*, Chicago, has commenced the installation of electric headlights on all of its locomotives, 2,500 in number. The improvement will be made at the rate of from 75 to 100 engines a month.

PICKLING *versus* SAND-BLASTING.—In a paper read before the American Drop Forge Association it is stated that in the drop-forge industry pickling, tumbling and sand-blasting are the three principal methods used for cleaning. Pickling is the preferable way if the acids and salts are thoroughly washed from the surfaces of the forgings. There is no favourable comparison between pickling and sand-blasting. In the former method all surfaces are cleaned thoroughly from oxides or foreign substances, which are detrimental to the machining operation, while in the tumbling and sand-blasting fine sand is hammered into the surfaces. The resulting cost of machining is from 300 per cent. to 400 per cent. more than that of pickled forgings. Moreover, the drop-forgings that have small bores or indentations are not cleaned properly except by pickling. The additional cost of pickling is more than offset in the machining.

WALKING WITH ARTIFICIAL LEGS.—In the *Zeitschrift des Vereins Deutscher Ingenieure* of August 4, 1917, Professor R. Du Bois Reymond, of Berlin, points out that the designer of artificial legs for invalided soldiers must not rely only on what he is told by the patient and on what his own eyes tell him. To see, whether the limbs are really suitable requires a study such as the kinematograph enables the expert to conduct. Following the example of Otto Fischer when first studying the walking of man, he fastened, by means of straps, Geissler tubes to the outside of the legs of the subject, one along the thigh and one along the calf of the leg. The subject was then made to walk past the camera in a dark room. Reymond thus obtained diagrams consisting of four lines in each case, representing the changes in the positions of the legs, and he soon noticed that a man with one sound leg and one artificial leg does not walk normally, and a man with two artificial legs still less so. Normal walking is always progressive in space, but people with artificial limbs threw the limb forward too much and then drew it back again. There was hence an unconscious waste of energy, and discomforts arose for which the inexperience of the invalid might be more responsible than the design and construction of the artificial limb.